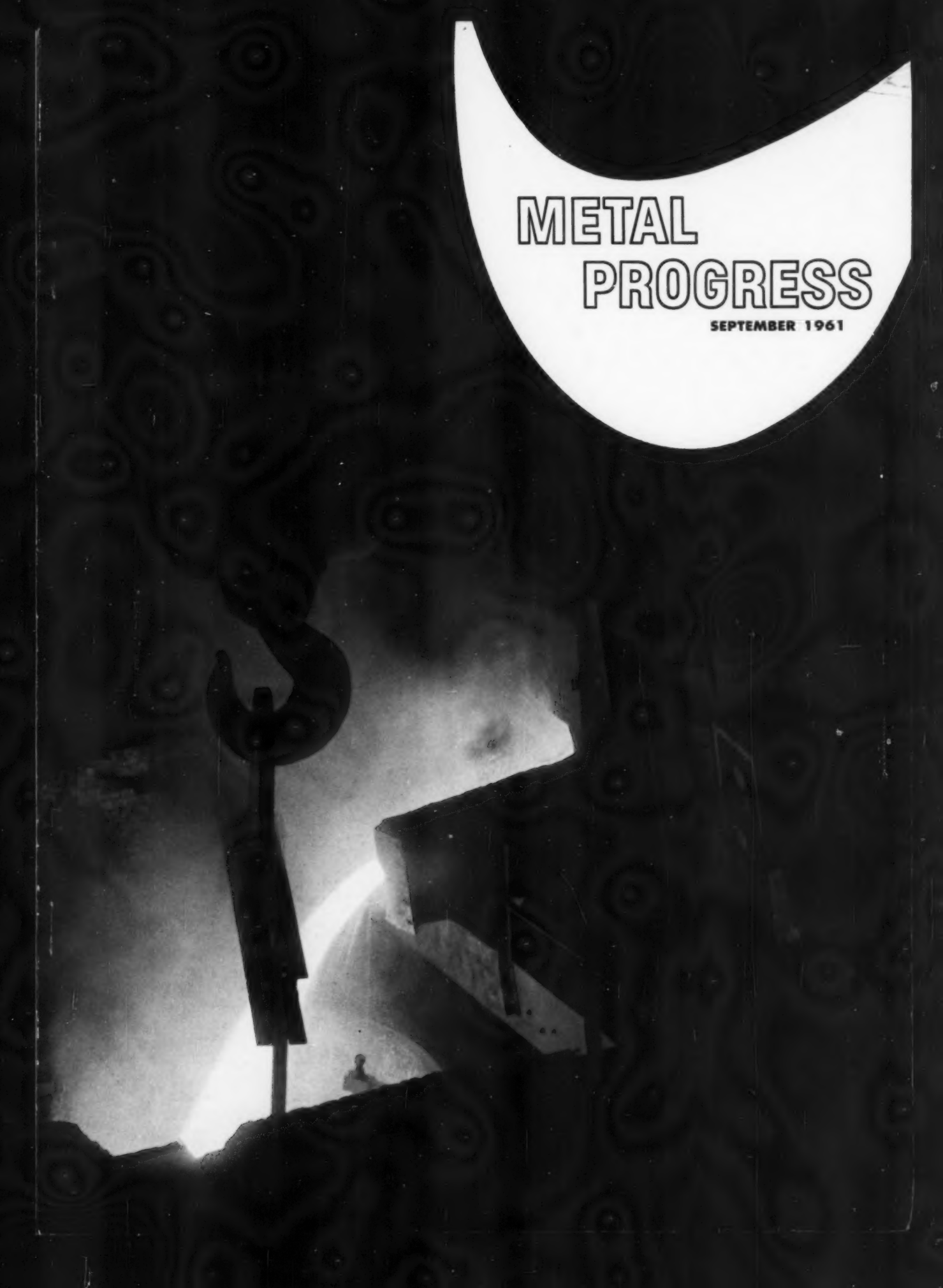
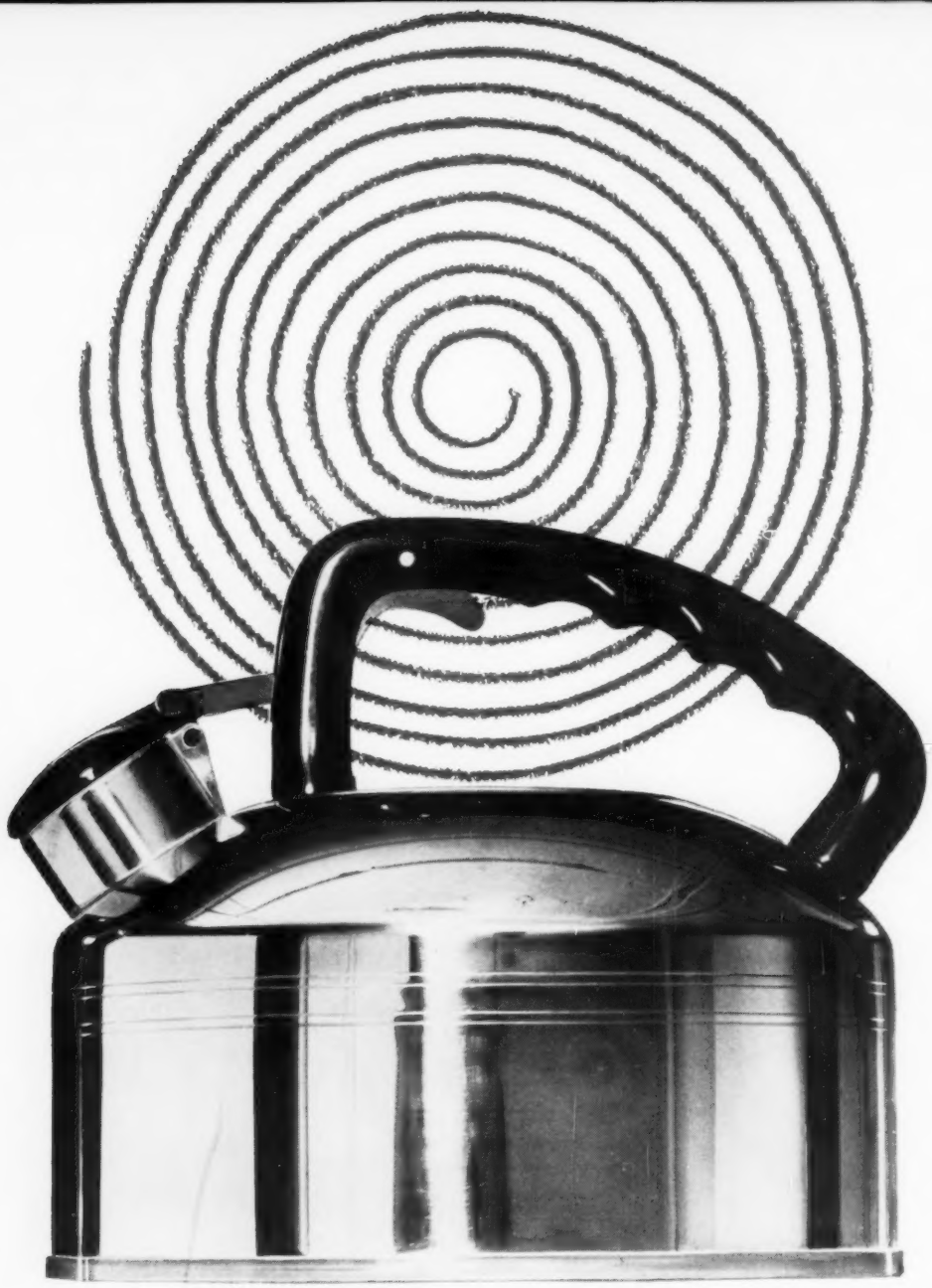

METAL
PROGRESS
SEPTEMBER 1961



OPEN UP: for better non-aging steels

Non-aging rimmed steels can be made by the Lee Wilson Open Coil Gas Alloying Process by using humidified hydrogen gas to remove carbon and nitrogen. These steels can be used as a less expensive replacement for aluminum-killed steels presently used in many critical applications. The steel mill yield for aluminum-killed steel is inherently lower than that of rimmed steel, and the surface quality of rolled aluminum-killed steel is characteristically poorer. Non-aging rimmed steel produced by Open Coil Gas Alloying therefore provides both economic and quality advantages. For further details, write *Lee Wilson Engineering Co., Inc., 20005 Lake Road, Cleveland 16, Ohio.*

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Lee Wilson

ORIGINATORS AND LEADING PRODUCERS OF OPEN COIL AND SINGLE STACK FURNACES

Metal Progress

September 1961 . . . Volume 80, No. 3

COVER: The striking photo on this month's cover shows molten stainless steel being poured from an electric furnace at Eastern Stainless Steel Corp., in Baltimore, Md.

Technical News in Brief

Dispersed Oxides Slow Oxidation of Nickel . . . Wider Galvanized Sheets Offer Fabrication Advantages . . . Cored Induction Furnaces From Italy Improve Melting Practices . . . Superconducting Alloys Fabricated Into Wire Form . . . Explosive Forming Simplifies Production of Large Parts . . . Progress in Nonmetallic Materials . . . Metal Show Issue Stresses Importance of Metal Selection 7

Progress in Brazing

The Evolution of Ductile High-Temperature Brazing Alloys, by D. C. Herrschaft 97

Silver brazing alloys containing small amounts of lithium, indium and palladium are now being used to bond stainless steel honeycomb, and alloys containing gold or palladium (or both) look promising for jet engine brazing applications.

Brazing of Components for Small Gas Turbine Engines, by M. J. Stern 101

Discussed here are techniques and controls employed at Boeing in joining engine components made of René 41 and other high-temperature alloys.

Calculating Cycles for Brazing, by H. M. Lampert, Jr. 106

When brazing stainless steel parts, it is necessary to know the times and temperatures at which they should be held during the cycle. This article describes the calculation of a time-temperature parameter.

No. 8 in a Series on Better Finishing

How to Get the Most From Phosphating Systems – II, by George H. Pimbley 108

The principles governing spray systems for zinc phosphating are similar to those of dip baths which were discussed last month. One difference is that the reactions must be accelerated to make up for the short processing time. In contrast, manganese phosphating, also described here, can only be done in dip baths because of the large amount of sludge which is always present.

Engineering Articles

Deformation of Metastable Austenite . . . an Interim Report on a New Process, by V. F. Zackay, W. M. Justusson and D. J. Schmatz 68

Mechanical properties of alloy steels strengthened by deformation in the metastable austenite "bay" of the T-T-T curve are affected in varying degrees by variations in grain size, tempering temperature, carbon content and other metallurgical factors.

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The coding symbols on articles in Metal Progress *refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*

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Metal Progress

Testing Protective Coatings on Metals, by Paul Smits 75

Designed to evaluate anodic coatings on aluminum, a scrape-abrasion apparatus can also be used to test lacquer, porcelain enamel, and other nonconductive coatings.

Designing a Weldable Alloy Using Metallurgical Parameters, by W. N. Platte 80

The general aspects of developing alloys for weldability involve metallurgical and physical data. These parameters are applied to the design of weldable molybdenum alloys.

A New High-Strength Aluminum, by J. A. Nock, Jr., Marshall Holt and D. O. Sprowls 87

Initially introduced as an aircraft forging alloy for highly stressed parts operating at 500 to 600° F., alloy 2219 has demonstrated other outstanding characteristics – good weldability, high strength, and resistance to stress-corrosion cracking – that make it suitable for applications in transportation, missiles and the chemical process industries.

Why Does Stainless Steel Corrode? by Morgan Sinclaire and Eugene Phillips 92

Unexpected corrosion of stainless steel can occur unless certain precautions are taken during fabrication and while parts are in service. Sensitization, carburization, sources of hydrochloric acid and dirt are the main causes of failure.

Guest Critical Point

How Should You Evaluate High-Strength Materials? by G. K. Manning 65

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PRESS BREAKS

As the September issue went to press, the editors turned all of their efforts to the special Metal Show issue which will come to you next month. This issue will bring you a number of special reports on "What Metal Shall I Use?", designed to help you do a better job of selecting and processing metals. Adding to the permanent value of the issue is a new feature – the M-P Fact Sheets. These accompany each article and list the important metals, alloys, their properties and, in some instances, proper processing, which engineers should consider for such applications as high-strength welded structures, for cryogenic vessels and high-temperature service, in heat treated parts for automobiles, tractors and trucks, for home appliances and business machines, and for nitrided parts and ferrous castings. They will be set in a new type face to make the comprehensive data as easy to read as possible.

And to aid you in making your final plans for the Metal Show, the October issue of *Metal Progress* will also carry the program of all the technical sessions (along with many abstracts of the papers that will be presented) and a list of all show exhibitors.

Planning the Metal Show issue began some time ago. In fact, as one of February's worst snow storms swept off of Lake Erie, the original theme was conceived. In March, the prospectus of the issue took shape, and the editors began gathering an extensive amount of timely information by letter, telephone and visits with technical experts in industry. During April, May, June and July – as time could be spared from preparation of the regular issues of *Metal Progress* – we continued the task of assembling, editing and writing to put the October issue into the form in which it will reach you. We owe much to the enthusiasm and cooperation of many technical men in the metalworking industry who contributed the information upon which the issue is built and then reviewed each of the articles and Fact Sheets to insure their accuracy.

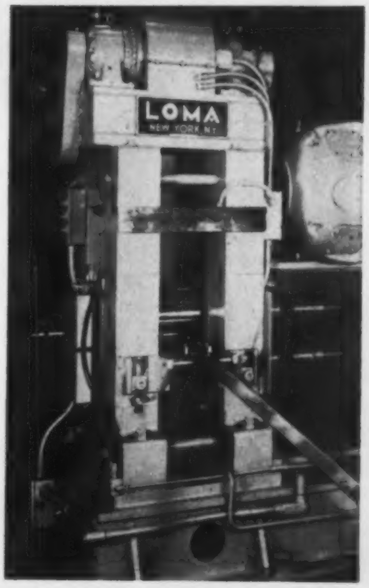
Although a lot of travel and contacts were needed to develop the editorial content of the October issue, even in the normal course of activities the editors do considerable traveling to attend technical press conferences and to gather information for specific articles. In recent visits, for example, Ralph Dermott (second from left in the upper photo) visited Ipsen Industries, Inc. in Rockford, Ill. to attend a conference on vacuum heat treating. And Fred Siegrist (second from left in the lower photo) traveled to Kokomo, Ind., to visit Haynes Stellite and learn of its activities in the production and processing of refractory metals.

These trips, although sometimes hectic, are often welcome changes from the office routine at Metals Park, but more important, they help us keep abreast of progress in metalworking technology – progress which we can pass along to you.

The Editors

NEWS FROM

LOMA



A wide variety of metallurgical processing work can now be performed by a single mill facility due to the development of this compact and versatile LOMA 2-high/4-high Combination Rolling Mill. The equipment is suitable for both hot and cold work, and allows both shapes and flat stock to be rolled, with or without the application of tension.

The machine is equipped with extra large capacity mill housings, roll journals, universal spindles and drive transmission. This heavy-duty design allows the mill to take reductions of more than 50 per cent per pass while maintaining tolerances as close as 5 per cent of thickness.

Change-over from the 8½ in. x 10 in. 2-high to the 2½ in. & 8½ in. x 10 in. 4-high setup requires only 30 minutes. The 2-high arrangement is used for either hot or cold breakdown rolling of plate and sheet, and grooved rolls are also available to process rounds, squares and other shapes. In the 4-high setup strip is cold finish rolled to gauges as thin as 0.002 in.

The LOMA mill is furnished with high-strength steel housings, twin-handwheel or dual-motor wormdrive screwdowns, universal joint spindles, herringbone gearing, and an extra heavy-duty 25 h.p. variable-speed drive. The rolls are made of forged alloy steel and are hardened to 100 Shore Scleroscope. The roll necks are mounted in super-precision needle roller bearings having a total separating force capacity of 350,000 lbs. The bearings are continuously lubricated by a closed oil circulating system.

LOMA
MACHINE MFG. CO., INC.
114 East 32nd Street
New York 16, N. Y.

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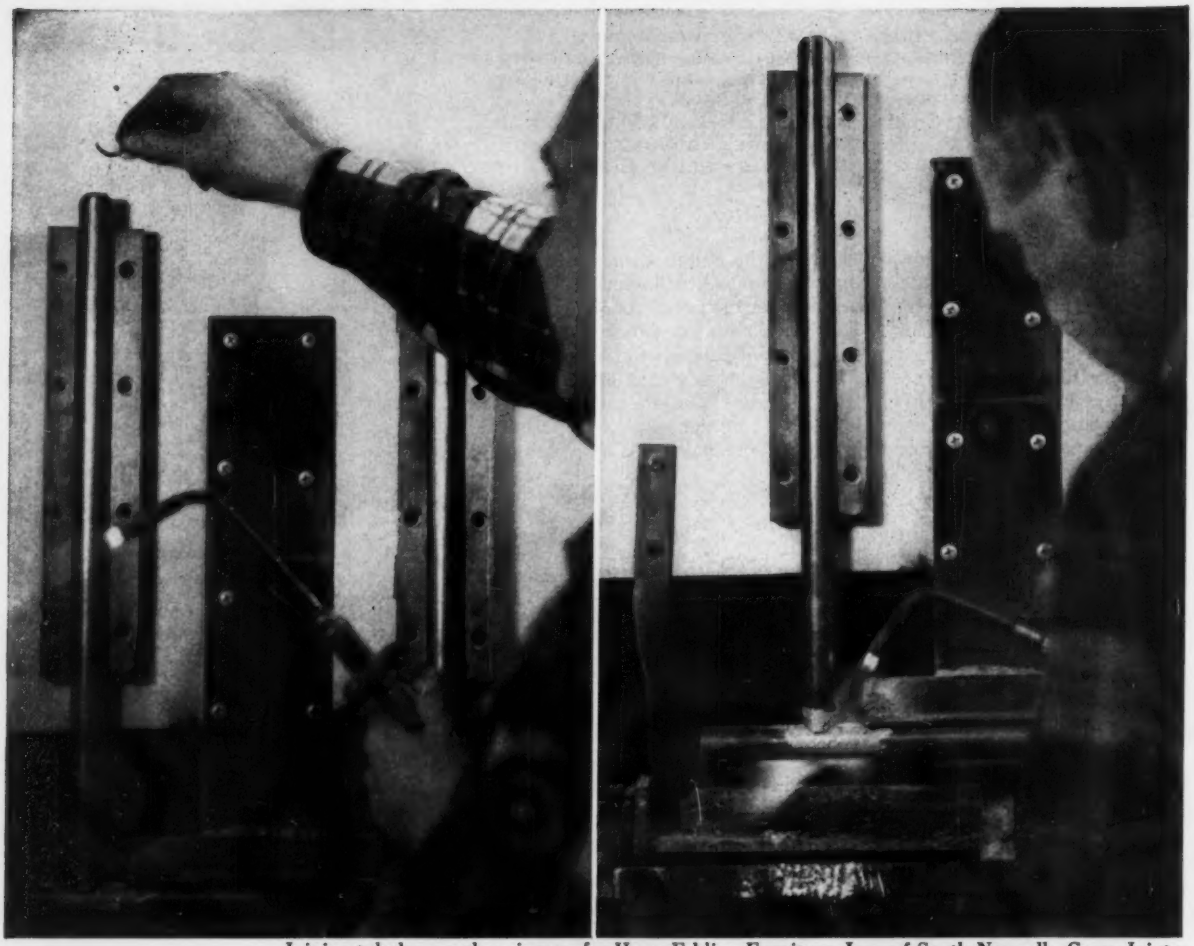


Joining tubular members is easy for Howe Folding Furniture, Inc., of South Norwalk, Conn. Joints are fluxed with Handy Flux, a half-circle preform of EASY-FLO brazing alloy is dropped down the tube and a torch is applied. Result: A smooth, strong joint quickly and economically made.

How Handy & Harman Brazing Alloys

GIVE FOLDING FURNITURE 100% JOINT RELIABILITY

The experience of Howe Folding Furniture, Inc., with silver brazing merits close attention if your operations involve metal-to-metal joining of any kind. Howe manufactures folding metal tables and seats for commercial, industrial and institutional use. You can imagine the hard usage the furniture has to take—yet survive indefinitely.

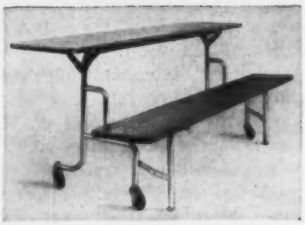
Some years ago, it was Howe's practice to purchase prefabricated steel tubular assemblies in which the joints were brass brazed on the outside surface. To improve their product, Howe thoroughly tested all joining methods, and decided to go over to silver brazing in their own plant, using Handy & Harman EASY-FLO Alloys 45 and 35. Look at the results:

Complete Joint Reliability: Since adopting silver brazing, Howe has completely eliminated the problem of broken joints.

Economy: Silver brazing costs Howe less than other methods, requires less heating time, simpler equipment, much less cleaning and grinding of joints.

Appearance: Silver brazing provides a smoother, more attractive joint, that can be plated directly.

Is it any wonder Howe says: "We'd stay with silver brazing even if it cost more." There are few fields of industrial activity where the strength, high production rates and economy afforded by the Handy & Harman family of silver brazing alloys cannot improve the look of the balance sheet. Interested in complete details? Just write for a copy of our Bulletin 20 — it's packed with engineering and application data.



Howe cafeteria table-bench is converted to an auditorium bench with backrest in a single motion. Silver brazed joints easily absorb strains.

HANDY & HARMAN

850 Third Avenue, New York 22, N.Y.
PLaza 2-3400

Circle 1159 on Page 48-B

Dispersed Oxides Slow Oxidation of Nickel

Recent experimental work has shown that small additions of insoluble oxides dispersed in a metal matrix can improve the oxidation resistance of the metal at high temperature. According to R. W. Harrison and J. G. Darrah, of Nuclear Materials and Research, Pratt & Whitney Aircraft-CANEL, Middletown, Conn., this characteristic has been used to advantage in the production of an oxidation-resistant, nickel-base sheet material which has high thermal conductivity. Elements in solid solution with nickel improve resistance to oxidation but they greatly decrease the thermal conductivity; small amounts of insoluble oxides have shown little effect on this property.

OXIDE LAYERS ON PURE NICKEL (500 ×)
Fissures in Oxide Permit Oxygen to Penetrate to Underlying Nickel

Not all oxides which increase resistance to oxidation are satisfactory from other viewpoints, however. For example, a ball-milled powder mix containing 10 vol. % Al_2O_3 (Φ.1 micron) in 5-micron carbonyl nickel powder, sintered to high density and oxidized at 1650° F., showed greater oxidation resistance than pure nickel, but all attempts to roll this material to 8-mil sheet were unsuccessful. A better substitute for Al_2O_3 is $NiAl_2O_4$ powder, formed by reacting finely divided NiO and Al_2O_3 at 2400° F. Dense sintered bars containing 5 to 10 vol. % $NiAl_2O_4$ in nickel, unlike the Al_2O_3-Ni material, can be rolled to thin sheet. A metallographic examination of the 8-mil sheet reveals that any agglomerates of $NiAl_2O_4$ break up due to the rolling operation and appear as stringers running in the rolling direction. This decreases the interparticle spacing of the oxide. The rolled product also exhibits better oxidation resistance than the as-sintered material.

Tests show that a critical thickness of oxide forms on nickel when it is exposed to an oxidizing environment at high temperatures. The oxide layer then becomes semi-adherent and develops fissures, thus opening new avenues for oxygen to come in contact with the freshly exposed nickel.

This behavior is evident when the continuous weight gain (because of oxidation) of unalloyed nickel samples is plotted as a function of time at exposure temperature. Such a curve for nickel tested at 1650° F. for various times reveals two points of inflection. One occurs at about 26 hr. (weight gain: 3.4 mg. per sq.cm.), an-

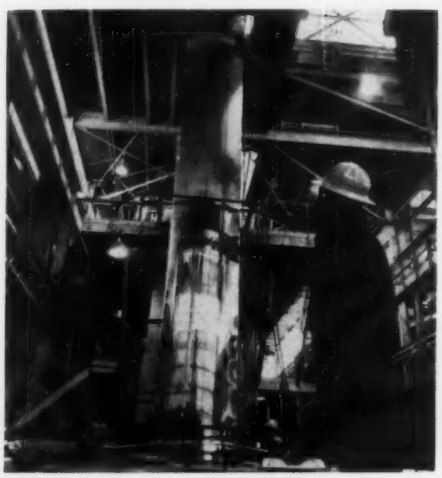
other at about 66 hr. (weight gain: 5.2 mg. per sq.cm.). The increase is oxidation rate at the inflection points at a 40-hr. interval and the behavior of the oxide film (its tendency to develop fissures) can be correlated by metallographic examination. Three oxide layers formed in 100 hr. during an oxidation test at 1650° F. can be seen in the micrograph. Significantly, Ni-$NiAl_2O_4$ sheet 8 mils thick does not show this effect at exposure times of up to 200 hr. This material not only oxidizes more slowly than unalloyed nickel (after 100 hr. exposure in moving air, Ni-$NiAl_2O_4$ sheet has gained about 3.5 mg. per sq.cm. whereas unalloyed nickel has gained about 7.0 mg. per sq.cm), it also develops an adherent scale.

Wider Galvanized Sheets Offer Fabrication Advantages

Automakers and fabricators of other metal products are using increasing amounts of galvanized steel in the fight against corrosion. In 1954 the average car contained only 8.9 lb. of galvanized sheet. By 1958 this had increased to 63 lb. per car and in 1961 it is estimated that a compact car employing the unitized body (which requires that all body members have good corrosion resistance) uses 100 lb. of zinc-coated steel. Galvanized steel in household appliances, air conditioners and vending machines, has increased steadily (24% gain in 1960). Fabricators of products for the agricultural industry – farm equipment, buildings and related products are also large users of zinc coated steel.

The increasing popularity of galvanized steel came to light last month when Armco Steel Corp. unveiled its new 72-in. continuous zinc coating line – the widest galvanizing unit of its type ever built. Availability of wider galvanized sheet is expected to offer advantages in fabrication. For example, in the manufacture of appliances and vending machines, according to Armco, the 72-in. material is expected to be employed in cabinets with the increasingly popular wrap-around design. The new continuous unit coats 300 ft. of strip per min. and can produce 30 tons of zinc-coated steel in sheet or coil form per hour.

Logan T. Johnson, Armco's president predicts increased use of galvanized steel by the auto industry and by other manufacturers. New surface finishes will stimulate this growth. For example, a spangle-free sheet, chemically treated for painting carrying a standard coating for full corrosion resistance is expected to be employed in automotive, appliance and architectural applications requiring corrosion protection and a superior finish. A new process to minimize but not eliminate spangle has been developed to satisfy surface requirements falling between standard and spangle-free sheets. Also, differential coatings are available where one side carries a standard weight zinc coating and the other has a minimum coating for better painting characteristics. Automobile rocker panels utilize this material, for example.



WIDER ZINC-COATED STEEL STRIP
Galvanized Strip, 72-In. Wide
Emerges From Molten Zinc Bath

Unlike batch-method, hot dip galvanizing, the continuous process deposits a coating with excellent adherence. The coating stretches and it will withstand as much drawing and forming as the steel basis metal itself without cracking, peeling or flaking.

Cored Induction Furnaces From Italy Improve Melting Practices

Foundries in this country are now being offered a line of novel melting equipment, the operating principles of which are new in application though they have been known for some time. Unlike the coreless high-frequency furnaces commonly in use here, these 60-cycle furnaces have a vertical core in the center around which the molten metal is stirred (horizontally) by induction. According to the originators and builders, Forni Elettrici A. Tagliaferri of Milan, Italy, this arrangement can be controlled to enable operators to stir the heat at the optimum rate needed for thorough mixing.

Technical

NEWS

In Brief

Furthermore, this control is such that little refractory erosion is experienced – reports from users throughout the world indicate that refractory life is 500 to 800 heats of cast iron, depending upon furnace capacity.

Though over 1000 furnaces built according to these principles are in use over the world, this country has but one installation to date. At South Bend, Ind., the Sibley Machine and Foundry Co. is now operating a 4½-ton receiver which is used for mixing cupola iron. Installed by Hevi-Duty Electric Co., Watertown, Wis., the American licensees of the Italian firm, this unit has many advantages. With it, Sibley can make any additions needed to bring the cupola iron into required specifications, and can also control the size of graphite flakes to such an extent that the tensile properties of the resulting castings are 20 to 25% higher than those of castings produced from comparable cupola iron.

Superconducting Alloys Fabricated Into Wire Form

Superconductivity, the absence of electrical resistance in materials near absolute zero (−460° F.), has received a great deal of attention lately. One reason is that several alloys have been found which are not only superconductors but are also capable of operating in high magnetic fields.

Work at Bell Laboratories and Atomics International, for example, has shown that Cb-Sn and Cb-Zr alloys exhibit these characteristics. The ability of materials to remain superconductive in strong magnetic fields offers the promise of more powerful electromagnets that are more compact and less expensive than those using conventional materials. The smaller electromagnets would also have use in communications, direct conversion of heat to electrical energy and in controlling the fusion reaction in atomic reactors.

Unfortunately, one of the problems has been the lack of commercial quantities of the Cb-Zr and Cb-Sn alloys in wire form. But researchers at Wah Chang Corp., Albany, Ore., have recently fabricated Cb-Zr (25 to 33%) wire with a diameter of less than 0.010 in. in lengths of about 1000 ft. Tests indicate that the wire will tolerate critical magnetic field strengths up to 80 kilogauss at current densities of about 1×10^4 amp. per sq. cm. An experimental magnet has been wound using this wire and will soon be tested to determine its maximum operating capabilities.

Compared with Cb-Sn alloys, those of Cb-Zr will become resistive when placed in a weaker magnetic field, but they present fewer difficulties because of their superior forming characteristics. Columbium-zirconium alloys are more ductile in wire form, and they are almost as strong as tungsten wire. They may also be fabricated without a protective sheath whereas Cb-Sn alloys must first be clad with columbium.

Explosive Forming Simplifies Production of Large Parts

It was pointed out in *Metal Progress* last month (see special report on high-energy forming beginning on p. 66) that one of the advantages of explosive forming is its ability to simplify the fabrication of large parts. For example, engineers at the Baltimore Div. of the Martin Co., where work on the method was begun in January 1960, say that they can eliminate much of the welding that is ordinarily needed in producing large structures such as fuel tanks for missiles.

In a scale model of one part, known as a torus tank, Martin engineers were able to reduce the number of separate pieces which make up the tank from 40 to 12. The amount of weld footage needed to join the pieces was also reduced by about 60%.

To make the complete tank, it must be formed in two halves (see photo). Six pieces of sheet metal were welded together into a form resembling a huge cake pan. This was placed in a die, filled

EXPLOSIVELY FORMED TANK SECTION
The Process Reduces the Amount of Welding Needed When Conventional Methods Are Used

Technical NEWS In Brief

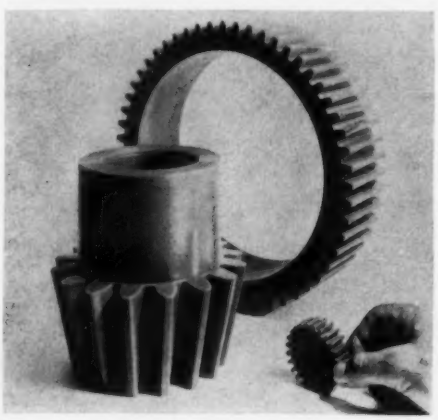
with water and securely fastened around its outside edge with a holddown ring to permit all air to be pumped out of the cavity between the die and preform. Detonation of the charge then expands the preform into the shape of a hollow doughnut.

Progress in Nonmetallic Materials

Large semifinished parts weighing as much as 700 lb. have been cast of nylon. After two years of field tests, engineers of Polymer Corp., Reading, Pa., report that the casting process can produce large shapes (see photo) by direct conversion of nylon from basic raw materials rather than from powders of nylon polymer.

An advantage of the technique is that casting can be performed at atmospheric pressure. Massive parts of nylon have not proved practical in the past because of high costs which would be necessary on tooling up for injection or extrusion molding of nylon polymers. In the new technique, a liquid nylon monomer is heated, then mixed with a catalyst and thoroughly agitated. Once it is poured in a mold, polymerization takes place and the nylon solidifies in a few minutes.

Although several types of monomer-cast nylons have been developed, most evaluation work has been performed with a grade designated as MC nylon 901. This formulation possesses chemical resistance, wear resistance and electrical properties similar to those of Type 6 and 66 nylons. Tensile strength is about 11,000 to 14,000 psi.; elongation, 20 to 30%; and modulus of elasticity, about 300,000 psi. Primary applications will be for parts that require wear and abrasion resistance in the absence of effective lubrication – bushings and bearings, foundry core boxes, gears, valve seats for ball valves. Under prolonged exposure, the cast nylon is limited to temperatures of about 250 to 300° F. Although it will fail quickly in strong acids, it is resistant to many mild acids and alkali solvents.



CAST NYLON GEARS
Direct Conversion of Monomeric Nylon Permits Large Parts To Be Cast

From Here and There

United States Steel Corp. has licensed a third foundry, Bonney-Floyd Co., Columbus, Ohio, to produce quenched and tempered castings of T-1 constructional alloy steel.

• • •

Discussed at International Nickel Company's Power Conference at Estes Park, Colo., early last month was a new alloy, IN-102. Designed for long-time service at temperatures up to 1200° F., the alloy has a Ni-Cr base and is strengthened with columbium, molybdenum and tungsten.

• • •

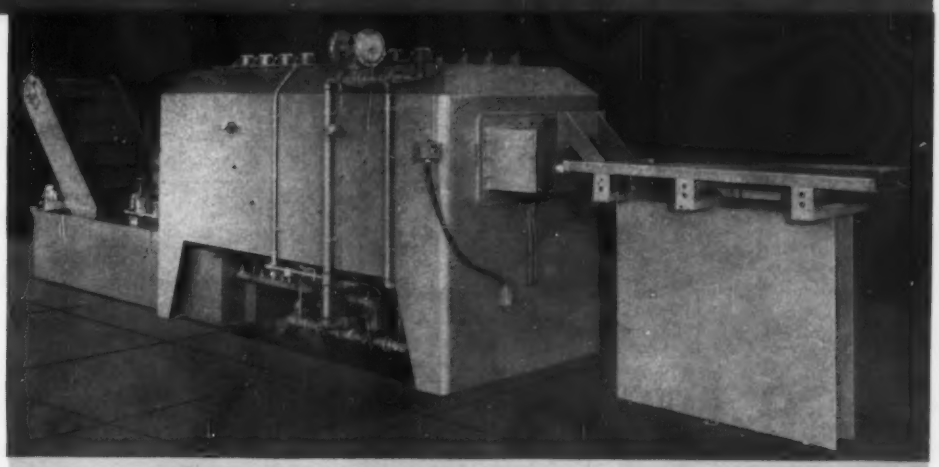
A blast furnace at Armco Steel Corp., Middletown, Ohio, averaged 2942 tons of iron per day during the month of June while operating with an all-taconite charge.

Metal Show Issue Stresses Importance of Metal Selection

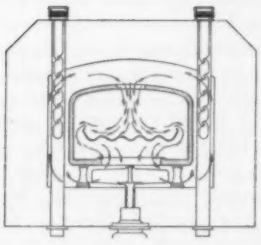
"What Metal Shall I Use"? is a recurring question being asked by engineers in industry today because their choice will determine the performance of the part and, just as important, the cost of producing it. Next month, *Metal Progress* will present in its Metal Show issue a group of special reports which set out to answer that question. Based on the theme "What Metal Shall I Use?", the issue will present articles dealing with metals for high-strength welded structures, steels for automobiles, truck and tractor parts, metals for cryogenic service, tool steels for nontooling uses and prefinished metals, to name a few of the topics discussed. To give the issue permanent value, almost all of the articles will include M-P Fact Sheets. These comprehensive data tables will list the metals and processes you need to consider in your everyday work.

new Ipsen shaker-hearth furnace with

100% forced convection heating



- Continuously Produces Bright Parts.
- Parts Heated By 100% Forced Convection For Uniformity of Temperature.
- Parts Individually Quenched For Uniformity and Maximum Hardness.
- New Shaker-Mechanism and Hearth Assures Uniform Case Depth.
- Patented Conveyor Prevents Parts Sticking.



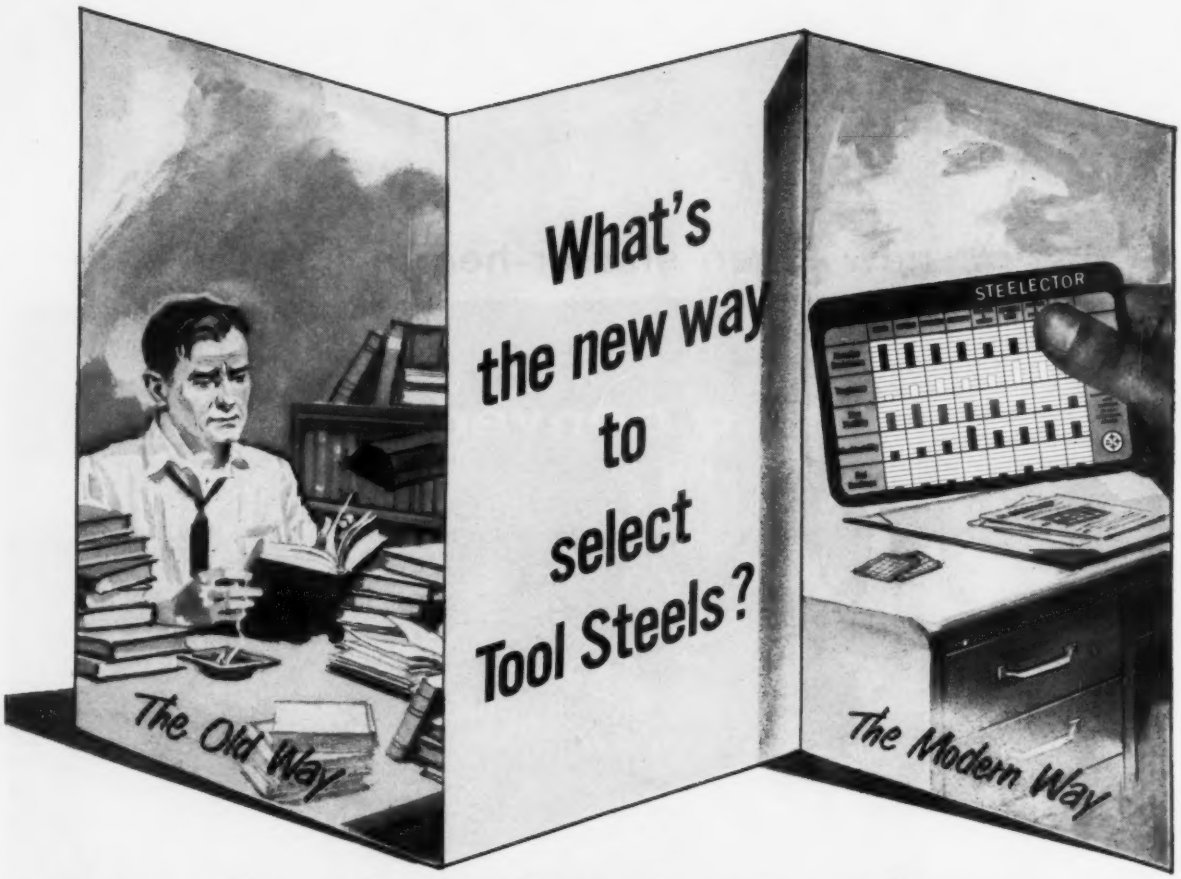
Ipsen 100% forced convection heating is achieved through a high-velocity directional flow of controlled atmosphere around heating tubes. The flow is directed against parts as shown, resulting in fast and uniform heating.

Ask for an Ipsen engineer to call and give you complete information relating to your work.

AUTOMATIC Ipsen HEAT TREATING UNITS

IPSEN INDUSTRIES, INC. DEPT. 723 P.O. BOX 500 ROCKFORD, ILLINOIS

Circle 1160 on Page 46-B



Use the A-L Steelector System

The man on the right is using the new way. With the new Allegheny Ludlum STEELECTOR he can select tool steels virtually at a glance. Best of all, he knows that his first choice is in stock—available right when he wants it. No longer does he have to waste hours looking through handbooks and catalogs only to find that he has selected a brand that is unavailable . . . or entails expensive delays because he must wait for the mill to make it.

With the STEELECTOR, picking the proper tool steel is an easy job. All you have to do is look at the STEELECTOR Card designed for the job at hand. There are STEELECTOR Cards covering general purpose tool steel applications, hot work applications, and high speed grades. A glance at the card compares the five basic tool steel properties—abrasion resistance, toughness, size stability, machinability, and red hardness—of each of the STEELECTOR tool steel grades.

Bar graphs show how the steels compare so it's simple to check the properties most important to you and pick the grade with the combination of properties you need. The three STEELECTOR Cards list grades that will suit 96 percent of all tool steel applications—as shown by an actual survey of the authoritative A-L Tool Steel Handbook.

Backing up the STEELECTOR Cards are Data Stock Lists for every grade. They list the complete necessary range of sizes and shapes available and typical applications. They also include heat treating and other data to assure you that you have made the proper selection.

You can put full confidence in STEELECTOR grades because they have been selected from the complete line of A-L Tool Steels and are made under the rigid quality control standards common to all A-L products.

To take the guesswork out of tool steel selection, ask your Allegheny Ludlum sales representative for your copy of a colorful STEELECTOR Bulletin that contains all three STEELECTOR Cards, describes the tool steels, and explains the Data Stock Lists, or write: ***Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pennsylvania. Address Dept. MP-9.***

STEELECTOR PROGRAM

ALLEGHENY LUDLUM

Tool Steel warehouse stocks throughout the country

2082

Circle 1161 page 48-B

Metal Progress

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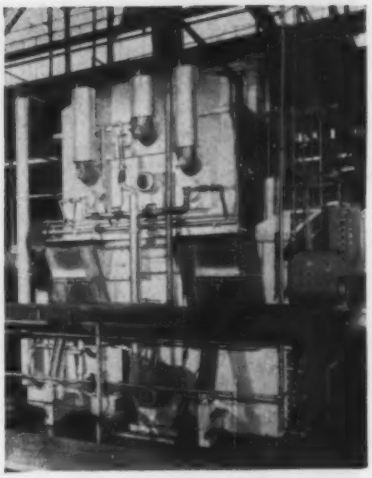

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For any of these processes:

- ✓ ANNEALING
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- ✓ CARBURIZING
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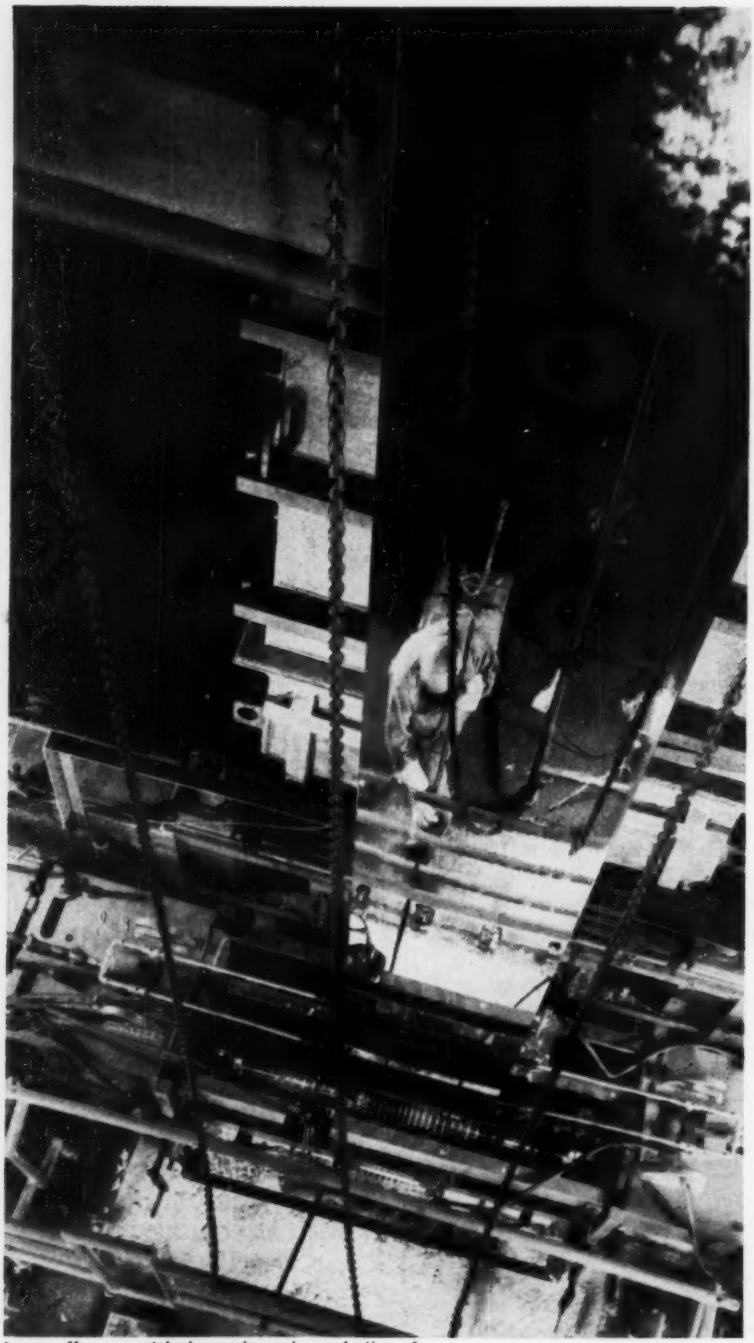
Phone TY 4-5700

44 YEARS OF ENGINEERING LEADERSHIP
Circle 1162 on Page 48-B

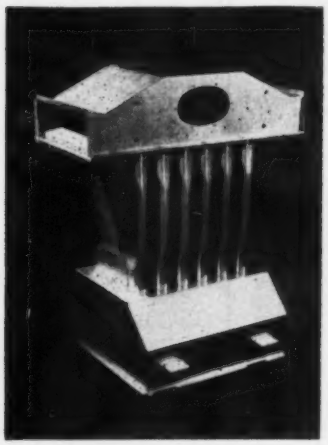


Armco offers unmatched experience in production of continuously zinc-coated and aluminum-coated steels.

Armco Offers

In 20 gage, 36-inch width, zinc-coated and aluminum-coated sheet steels produced by Armco would circle the earth more than 26 times!

Three varieties of Armco zinc-coated steel were used in these auto parts.

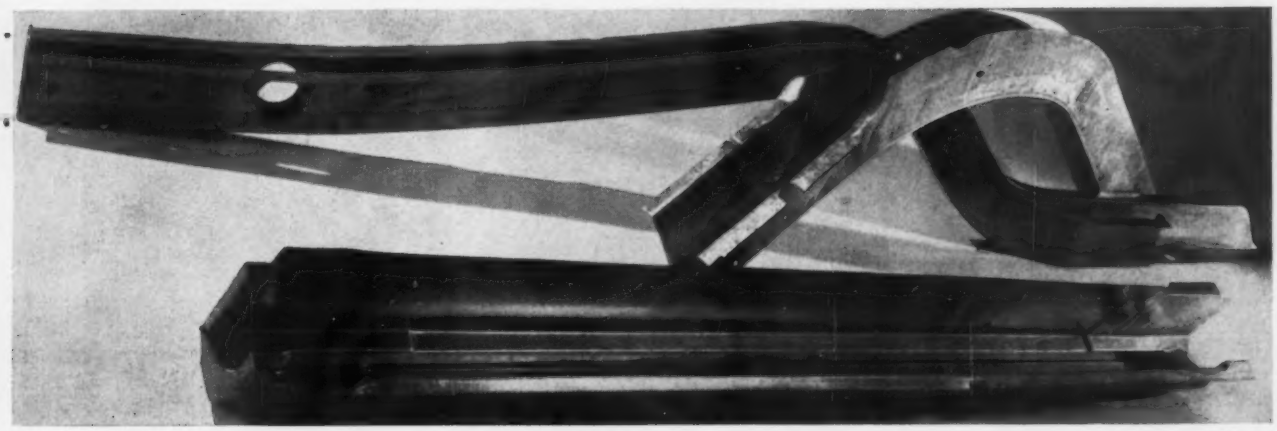


Heat-resisting parts, like this heat exchanger, serve longer when made from Armco ALUMINIZED STEEL.

Use this modern symbol of strength, economy, durability

Steel

633,000 "Miles of Experience" in Coated Steels



Quantity is one measure of experience. *Job-tailored quality* is another. It's the result of Armco's continuing refinements and innovations in practices for production of coated steels to meet specific needs. For example, consider Armco ZINCGRIP®, the original (1936) continuously hot-dipped zinc-coated steel. Today, it provides zinc protection and workability for hundreds of manufactured products. In addition, ZINCGRIP has taken on new dimensions—both figuratively and literally. Depending on gage and width, you can order varieties with or *without spangles*, and to speed production of painted parts, with mill-applied paint-holding surfaces. In 12 through 20 gage, ZINCGRIP also is now available in the widest hot-dip zinc-coated sheet produced—72 inches.

Two aluminum-coated types

For products requiring special kinds of durability, there are two Armco-developed hot-dip aluminum-coated steels. ALUMINIZED STEEL Type 1 provides low-cost resistance to combinations of heat and corrosion. Type 2 gives products outstanding life outdoors.

Measure quality of Armco's service-proved coated steels yourself. They're made to perform well—in production and in products. Mail the coupon for complete information.

New steels are born at Armco

Armco Division, Armco Steel Corporation
2041 Curtis Street, Middletown, Ohio

PLEASE SEND information on ☐ Armco ZINCGRIP ☐ Armco ZINCGRIP PAINTGRIP
☐ Armco ZINCGRIP A (spangle-free) ☐ Armco ZINCGRIP A, PAINTGRIP
☐ Armco ALUMINIZED STEEL Type 1 ☐ Armco ALUMINIZED STEEL Type 2

Name_____ Title_____

Firm_____

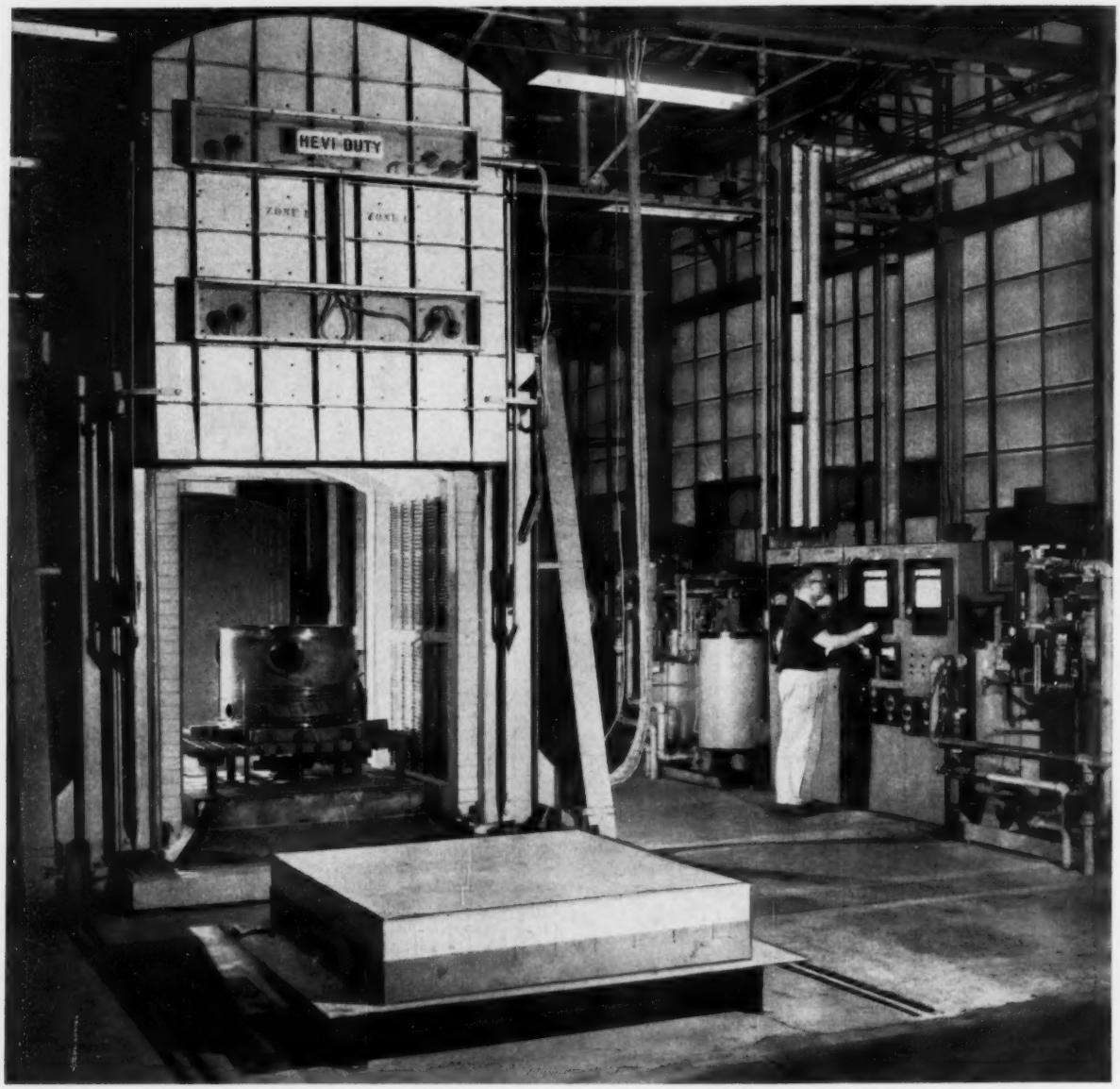
Street_____

City_____ Zone_____ State_____

ARMCO **Armco Division**

Circle 1163 on Page 48-B

Another example of Hevi-Duty Engineering Ingenuity



Special car bottom furnace moves to the work... solves head room problem, holds ± 10°F accuracy

Tapco Group, Thompson Ramo Wooldridge, Inc., Cleveland, wished to use bell furnaces but lacked necessary head room in the heat-treating area. Hevi-Duty engineered the perfect solution.

A special car bottom furnace was designed. It moves over the load . . . in contrast to the usual car bottom furnace where the load moves into the furnace. Two pedestals are used to permit continuous use of the furnace. Atmosphere-type retorts allow for slow cooling while a second load is being heated in the furnace . . . thus the furnace is used 24 hours a day . . . seven days a week.

Operating in the range of 1200°F, the furnace holds temperature uniformity to ±10°F. Work being tempered or stress relieved in this furnace has actually come out brighter than when it entered.

In more than four years of operation neither this Hevi-Duty car bottom furnace nor a duplicate furnace, installed a short time later, has required replacement of heating elements.

Talk with Hevi-Duty about your next heat-treating project. For information about a full line of electric or fuel-fired industrial furnaces and ovens, call your Hevi-Duty sales representative or write to Hevi-Duty, Watertown, Wisconsin. H-35-61

HEVI-DUTY

Electric and Fuel-Fired Industrial Furnaces and Ovens

B P C

Hevi-Duty Electric Company, Watertown, Wis.

A Division of Basic Products Corporation

Circle 1164 on Page 48-B

It's more than a matter of taste

Wherever food and metal meet, in a processing plant or kitchen, the metal is usually stainless steel. The flavor *and* purity of food are entrusted to stainless because no other metal matches its resistance to contamination and corrosion. And none—metal or plastic—is so durable, decorative and easy to clean.

Such complete trust in a product comes only from time-tested performance – the reason J&L consistent quality stainless steel is specified by manufacturers of equipment widely used by packers and processors, and by chefs in restaurants, hospitals and hotels. By delivering quality consistently, J&L helps the food industry safeguard its products, all the way from plant to palate.

Get consistent quality stainless steel from your J&L distributor, who is backed by the full facilities of J&L's research laboratories.

Jones & Laughlin Steel Corporation

STAINLESS AND STRIP DIVISION • DETROIT 34

STAINLESS

SHEET • STRIP • BAR • WIRE

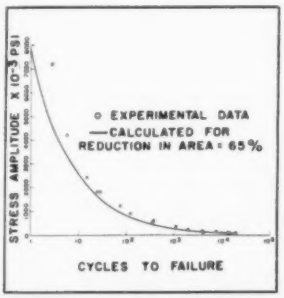
$$S = \frac{Ec}{2\sqrt{N}} + Se$$

A NEWLY DERIVED FORMULA FOR PREDICTING MATERIAL PROPERTIES . . . . . IN ADVANCE

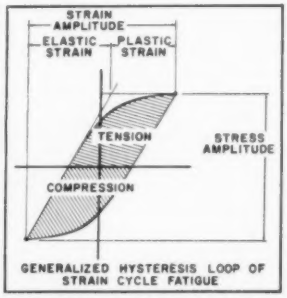
Instron is proud to have played a part in the development of a workable equation for predicting the low-cycle fatigue resistance of metals (and other materials). Low cycle fatigue deals with mechanical and thermal cyclic strain in materials from ¼ cycle up to approximately 10^5 cycles. Recent investigations have shown the tremendous importance of establishing reliable design criteria in this critical plastic strain range.

No — we can't take credit for the equation itself (which you can study at your leisure below.)* But we are responsible for the Instron Universal Tester, equipped with reverse stress cycling controls, which helped to prove that the equation was workable. Data obtained from low-cycle strain fatigue tests on 12 different materials, conducted on the Instron, corroborated the equation.

Which is yet another instance of what we mean when we say "you can do more with an Instron". If you have any problem at all related to materials testing, you should (at the very least) have the complete Instron catalogue. Also available: our ever-growing library of articles on advanced testing techniques, covering many fields. Yours for the asking — just mention your particular field of interest.



Typical curve (for 1018 carbon) shows correlation between Instron data (dots) and formula (solid lines).



Generalized hysteresis loop of strain cycle fatigue.

Accuracy of cycling data provided by Instron Universal Tester furnished a reliable standard against which to check new formula.

*$S = \frac{Ec}{2\sqrt{N}} + Se$ — New formula for stress amplitude of a material is based on just 3 knowns, all easily arrived at by conventional test methods: 1) E, modulus of elasticity; 2) c, a constant easily related to the per cent reduction in area and 3) S_e, the endurance limit or yield stress point. N represents cycles to failure. Satisfactory correlation with experiments up to 10^5 cycles to failure was found. For more insight into this fascinating development, drop us a line.

For advanced stress analysis equipment look to

The Instron comes in various models and sizes to suit the widest applications for tests under all kinds of environmental conditions Shown: Floor Model — load ranges from 2 grams to 10,000 lbs

INSTRON

2507 Washington Street, Canton, Mass.

THIS IS THE REGISTERED TRADE-MARK OF A COPPER ON THE MOVE

The electrical-electronic industries in particular are making more and more use of the benefits inherent in OFHC* brand copper.

OFHC brand copper is more than just a deoxidized copper. It's a copper designed to be oxygen-free from the start to the end of its processing. An AMCO designed method excludes any chance of oxygen absorption.

To fabricators this means good ductility and workability—so necessary, for example, in wire drawing. Too, they can get fine finishes on tough jobs such as cold hobbing.

Users prefer OFHC brand copper because, along with other qualities, they are assured of high uniform electrical and thermal conductivity. Extra resistance to oxide scale flaking at higher-than-usual temperatures is another advantage. Characteristics like these make OFHC brand copper the choice for such critical applications as klystrons, multiple cavity magnetrons, cyclotrons and electron tubes requiring glass-to-metal seals.

Learn how OFHC brand copper can benefit you. Contact the Technical Service Section of Amco.

AMCO, a division of American Metal Climax, Inc.
1270 Avenue of the Americas, New York 20, N.Y.
Detroit • Chicago • Los Angeles

Partial Listing of Uses for OFHC Brand Copper...

Anodes for plating
Anodes for vacuum tubes
Armature windings
Biposts for high-wattage lamps
Busbars
Coaxial cable
Commutator bars
Connectors in signal relays
Control cables
Electronic power tubes
Engravers plates
Flexible cables, cords, leads
Flexible shunts
Ground leads
Hollow conductors
Jumper cables
Lead-wire lamps and vacuum tubes
Locomotive wiring
Motor leads
Nuclear Research Equipment
Radar and other electronic equipment
Reflectors in photo bulbs
Rotor conductors for generators and motors (especially for extra large units)
Silicon rectifier bases
Thermostatic control devices
Transformer windings
Transistor bases
Submarine cable conductors

• For the extra rigid requirements set by the electronic industry, Amco also produces "Certified" OFHC brand copper. Guarantees include a very low impurity content of high-vapor-pressure elements along with a higher resistance to hydrogen embrittlement than specified by ASTM #170-47, Section 6.

Circle 1074 on Page 48-E

KNOW YOUR ALLOY STEELS . . .

This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many who may find it useful to review fundamentals from time to time.

Steel *for Strength*
. . . Economy
. . . Versatility

Tests for Determining Mechanical Properties of Alloy Steels

The types of tests used to evaluate the mechanical properties of an alloy steel depend upon the end use of the steel involved. Mechanical properties are determined usually by tension, bend, and hardness tests, and by a group of special tests employed on tubular and wire products.

(1) *Tension tests* provide means of determining tensile strength, yield point, yield strength, proof stress, proportional limit, per cent elongation, and per cent reduction of area. This sort of test subjects the steel to stresses resulting from the application of an axial tensile load to the specimen ends, the load being sufficient to rupture the specimen.

(2) *Bend tests* often aid in determining the ductility of steel. The severity of such a test depends largely upon the bending radius used. Several factors influence the length of radius, including thickness of the test specimen, width of test specimen, direction of test, chemical composition, tensile strength of specimen, etc.

(3) *Hardness tests* determine the steel's resistance to penetration. This characteristic is most commonly measured by the Brinell Test or the Rockwell Test. In the former, pressure is applied to the surface of a test specimen by means of a ball 10 mm in diameter. Two diameters of the resulting impression are measured and averaged; the average is converted to the hardness number by means of a conversion table. In the Rockwell Test, the degree of hardness is read on a gage; hardness is measured by the penetration of a diamond point or a 1/16-in. steel ball. Rockwell "C" scale readings are used in connection with the diamond point; "B" scale in connection with the steel ball. The "C" and "B" are the most commonly used of the several Rockwell scales.

(4) *Special additional tests* are often made on tubular and wire products. These include such items as hydrostatic and manipulating tests, and torsion and wrapping tests, the latter two being used only with wire.

The subject of testing and its relationships to the end uses of alloy steels has been given broad study by Bethlehem metallurgists. If you desire, they will be glad to discuss any phase of it with you, and also give unbiased opinions on such matters as analysis, proper selection of steels, machinability, etc. Call for their services at any time.

And when you need alloy steels, remember that Bethlehem furnishes the entire range of AISI standard analyses, as well as special-analysis steels and all carbon grades.

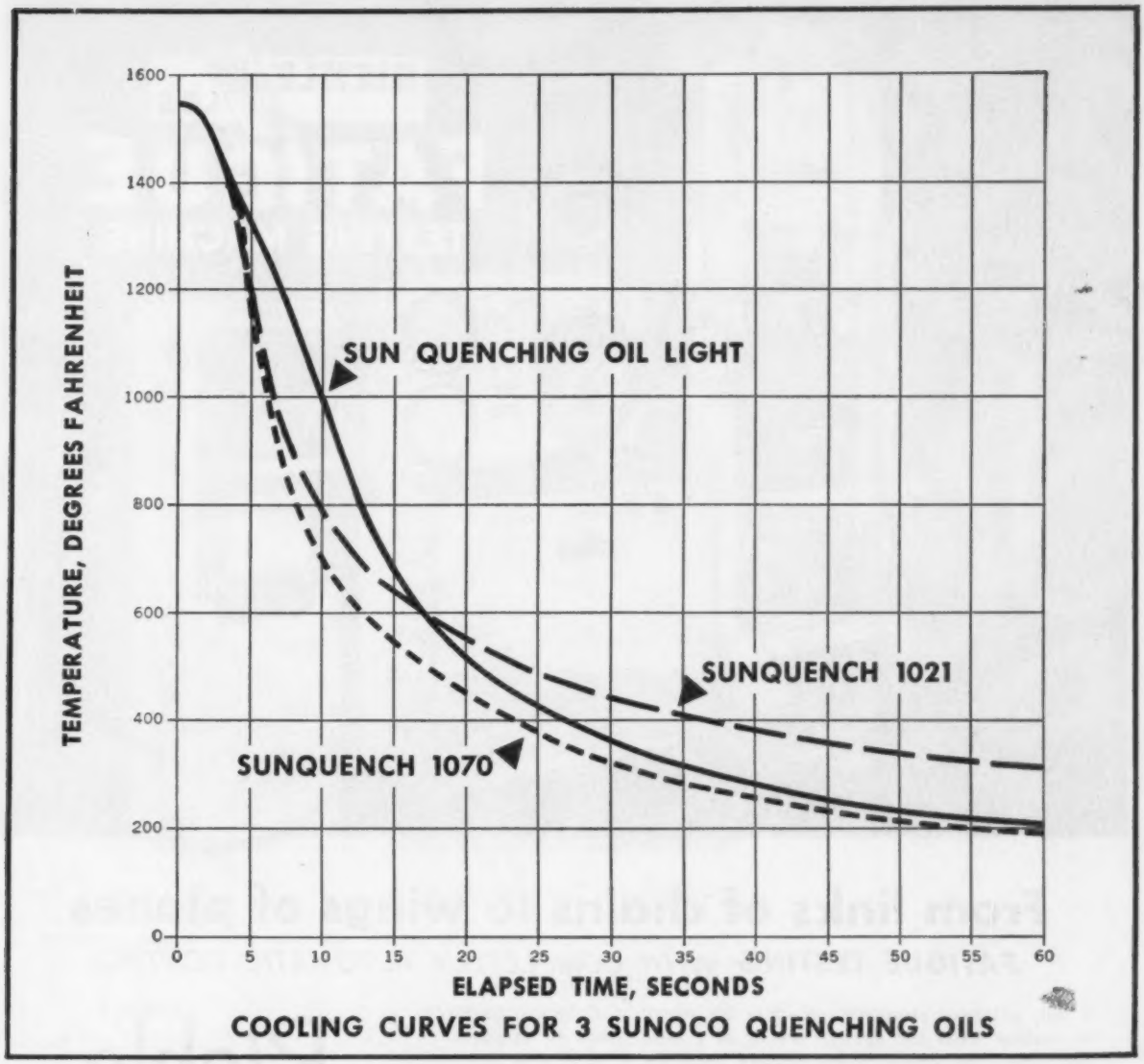
This series of alloy steel advertisements is now available as a compact booklet, "Quick Facts about Alloy Steels." If you would like a free copy, please address your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA. *Export Sales:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

Circle 1075 on Page 48-S



COOLING CURVES FOR 3 SUNOCO QUENCHING OILS

You'll find a job-fitted quenching oil to meet every need in the *full-range* Sunoco line. Above are cooling properties of our more widely used quenching oils. (1) Sun Quenching Oil Light—a premium quality, low cost regular oil. (2) Sunquench 1070—for minimum distortion, deeper hardness and fastest quenching you can get. (3) Sunquench 1021—minimum distortion, maximum hardness in 200-300 F oil temperature range.

There's a Sunoco quenching oil just right for you!

SUNOCO
Quality . . .
THE BEST ECONOMY OF ALL

From Sun's full line of quenching oils you can get *exactly* the quality you need to do the job right. There's no need to shop around, or to deal with two or three suppliers. If you quench with oil, Sun has the product. See your Sunoco man . . . or write to Sun Oil Company, Philadelphia 3, Pa., Dept. MP-9. In Canada: Sun Oil Company Limited, Toronto and Montreal.

PIONEERING PETROLEUM PROGRESS FOR 75 YEARS

Circle 1076 on Page 48-B

From links of chains to wings of planes

FATIGUE TESTING WITH COMPLETELY AUTOMATIC CONTROL

A fully automatic programer multiplies the versatility of the first machine to combine static and dynamic testing in a basic system of components. Endurance limit tests on either standard specimens or entire structures can be programed according to pre-set load levels, frequency and number of cycles. The automatic program unit governs cycles varying from 10,000 to 10,000,000 before repeating. Manual control can take over at any point in the test program to apply severe overloads at random intervals. RIEHLE-LOS Hydraulically Actuated Fatigue Testing Machines offer dynamic capacities of from 12,000 to 300,000 pounds.

GENERAL PURPOSE TESTING CYLINDERS permit the application of flexural stresses to complete assemblies, such as aircraft wings and fuselages; hull sections of ships; engine parts; bridge girders and concrete beams. Loads of varying frequency and magnitude can be delivered either simultaneously or in sequence.

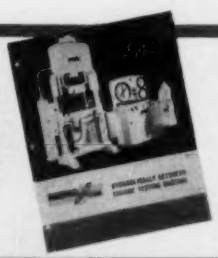
Riehle®

RIEHLE TESTING MACHINES DIVISION OF
American Machine and Metals, Inc.
EAST MOLINE, ILLINOIS

Divisions of American Machine and Metals, Inc.

TROY LAUNDRY MACHINERY • RIEHLE TESTING MACHINES • DE BOTHEZAT FANS • TOLHURST CENTRIFUGALS • FILTRATION ENGINEERS • FILTRATION FABRICS • NIAGARA FILTERS • UNITED STATES GAUGE • AUTOBAR • AUTOMATIC DEVICES • LAMB ELECTRIC COMPANY • HUNTER SPRING COMPANY GLASER-STEERS CORPORATION

NEW BULLETIN describes the RIEHLE-LOS Hydraulically Actuated Fatigue Testing Machine — complete with specifications, accessories and hydraulic flow charts. MAIL COUPON FOR YOUR COPY.



RIEHLE TESTING MACHINES Dept. MP-961
Division of American Machine and Metals, Inc., East Moline, Illinois
Please send Bulletin RF-2-61 RIEHLE-LOS Fatigue Testing Machine.

NAME _____
COMPANY _____
ADDRESS _____
CITY & ZONE _____ STATE _____

Circle 1077 on Page 48-8

NEW PRODUCTS

Nonferrous

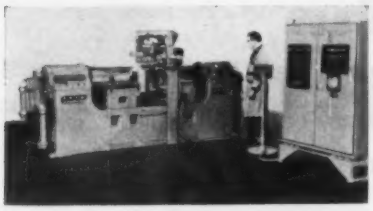
High-Strength Copper Alloy

"Cufenloy-40", containing 56% Cu, 41% Ni, 2% Fe and 1% Mn, has the high strength (85,000 psi. tensile) of most nickel alloys but costs about one-half as much. Intended for use in condenser tubes, the alloy can withstand the 600° F. temperatures required in high-pressure feed-water heaters for the larger power stations being built today. The strongest copper-nickel alloy available, Cufenloy-40 derives its high strength from a combination of alloy components and cold drawing. *Phelps Dodge Copper Products Corp.*

For further information circle No. 865 on literature request card, p. 48B

Tooling

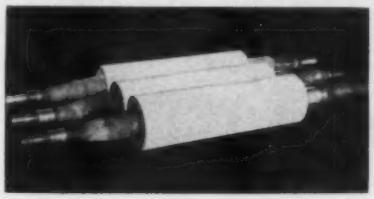
Automatic Drop Forging



Chambersburg Engineering Co. is introducing a Cecomatic Processing System for the automatic production of drop forgings in jobbing lot quantities. The setup consists of a "Model C" Impacter, a program-controlled feed device, and an automatic gas-fired furnace. Three sizes of Impacters (horizontal hammers) accommodate a range of forgings comparable in size to those made in gravity drop hammers of 1000 to 3000 lb. falling weight. Capable of producing forgings at rates far in excess of conventional methods, the unit has the flexibility to change jobs quickly on short runs.

For further information circle No. 866 on literature request card, p. 48B

Rolls for Annealing Furnaces



An extremely hard coating, "Duralize 505", applied to furnace rolls at 15,000° F. eliminates a pickup problem and gives a much longer service life — up to several months without refinishing — compared to several hours for alloy steel rolls. The thin, sapphire-hard coating is applied to centrifugally cast high-alloy steel rolls — solid or sleeve type — and is unaffected by high furnace temperatures. *The Duralloy Co.*

For further information circle No. 867 on literature request card, p. 48B

Giant Stretcher-Twister

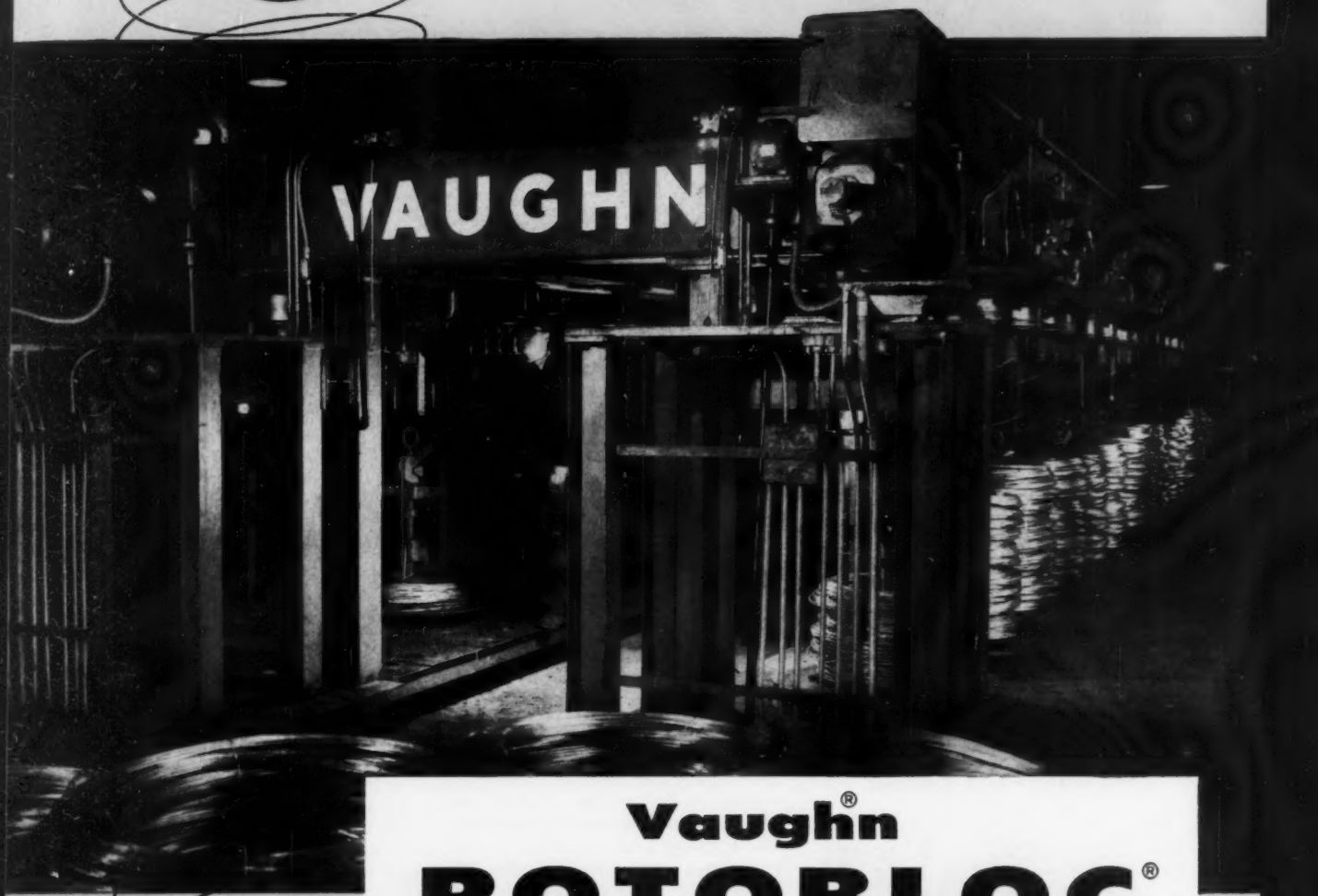
A 400,000-lb. stretching and twisting machine made by *Loma Machine Co.* can process aircraft and other structural sections up to 30 ft. long. Hydraulically actuated, the stretching speed is infinitely variable up to 25 in. per min., while twisting (200,000 in.-lb. torque capacity) is performed at the rate of ¼ rpm. All gripping jaws open and close by air cylinder and the machine features an intermediate head which is movable along the entire bed so that it can be engaged at any point on the work.

For further information circle No. 868

Large bundle–non-stop operation

without twist!

FOR USS AT DONORA WORKS, AMERICAN STEEL AND WIRE DIVISION



Vaughn® ROTOBLOC®

GALVANIZING · ALUMINIZING · PATENTING

This impressive 32-block Rotobloc installation underscores the increasing acceptance of Vaughn non-stop bundle production by leaders of the wire industry. The Vaughn Rotobloc, operating at the end of your wire processing lines, assures uninterrupted flow that means better deliveries for the customer and lower costs in the mill.

● This machine may be built in any number of blocks, and can also be designed for drum payoff, if desired. Size range is from 16 gauge galvanized to 13/32" patented wire. For additional details, write.

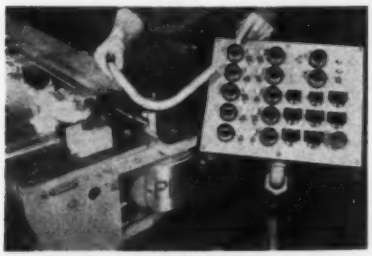
THE VAUGHN MACHINERY COMPANY

CUYAHOGA FALLS, OHIO, U.S.A.

COMPLETE COLD DRAWING EQUIPMENT—Continuous or Single Hole . . . for the Largest Bars and Tubes . . . for the Smallest Wire . . . Ferrous, Non-Ferrous Materials or their Alloys.

Circle 1078 on Page 48-B

Bend-Angle Selector



With the "Dial-A-Bend", an electronic angle-of-bend selector, more profitable handling of short-run bending operations is attained. An unskilled operator can now program bend angles from blueprint specifications, substantially reducing setup time. By setting compensator dials, spring back and other correction factors can be accommodated. Units are available on new or in-service rotary bending machines and bending presses. *Pines Engineering Co.*

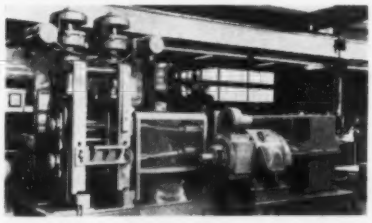
For further information circle No. 869

Electrodes for Electrical Discharge Machining

A new type of graphite stock for electrical discharge machining operations has been announced by *Speer Carbon Co.* "Kostkutter" graphite stock is capable of removing large volumes of metal while remaining in a relatively uneroded state. This means fewer electrodes are used, less down-time is reqiured, and less eroded material must be filtered from the dielectric oil. Its resistance to edge breakdown assures good cavity detail. Readily machinable, the stock is produced in a large number of standard plate sizes up to 12 by 12 by 2½ in. thick.

For further information circle No. 870

Versatile Rolling Mill



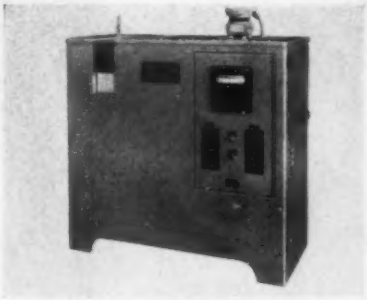
A 2-high/4-high 14-in. rolling mill, designed for hot and cold reduction of high-strength alloys, is used as a 2-high hot-breakdown mill, as a 2-high cold-intermediate mill, as well as a hot and cold rod-reducing mill. Precise roll adjustment is provided by two remote-controlled screwdown systems (employing the "moving screw" principle) and each is equipped with its own gear motor. A d-c. variable-speed drive powers the mill and offers rapid reversal, desirable for hot rolling. *Stanat Mfg. Co.*

For further information circle No. 871 on literature request card, p. 48B

Heating

Reciprocating Furnace for Bright Hardening

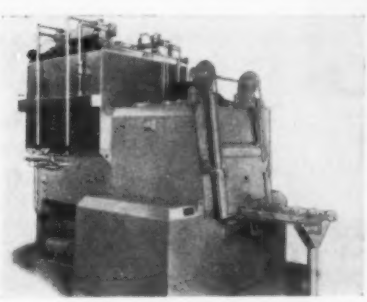
A "shaker" furnace made by *C. I. Hayes* offers high-volume bright hardening of very small pieces such as watch and photographic parts as well as ball bearings and instrument components. The "Model FLA-12" furnace heats up to 1900° F., max., within 3 min. Parts to be treated are loaded into a hopper and fall into an Inconel tube – which is a combined heating element, retort, and conveyor. Vibratory controls govern the flow rate of parts as they progress down the tube to an oil quench. The unit maintains an optimum protective atmosphere within close tolerances, thus assuring virtually a "no-reject" output.



For further information circle No. 872 on literature request card, p. 48B

Controlled Atmosphere Furnace

Designed for automatic operation, this furnace transfers work by means of a high-speed roller-chain system, operating out of the furnace heat. Radiant tubes, muffle, and fan are



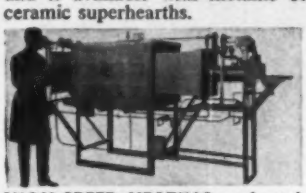
Ed Johnson, Furnace Application Engineer, talks about

SINTERING STAINLESS

Whether you're working with cermets, ceramics, refractory metals, or stainless steel powder compacts, Hayes has the *right* furnace and the *right* atmosphere to give you best results at lowest cost.

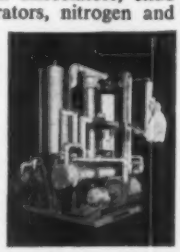
PRECISE SINTERING TEMPERATURES are important for effective bonding of compacts. The Hayes Type M-Y High-Temperature Furnace provides the exact, uniform heating required — has straight-through design for easy operation.

ECONOMICAL, TOO, the Hayes Type M-Y furnace needs only modest power input for temperatures to 3300°F with Moly elements. It can be used with reducing atmospheres for close control research or full-scale production, and is available with metallic or ceramic superhearths.



HIGH-SPEED HEATING and cooling cycles mean big production with the Hayes Model HT/HV Vacuum Furnace. A full-production size vacuum furnace, this Hayes unit is cold-wall designed for compactness as well as operating comfort. Heat-up to 3000°F range and over in minutes, with low voltage elements. High vacuum to 0.1 micron . . . low leak rate.

THE RIGHT ATMOSPHERE is available from the complete Hayes line –ammonia dissociators, endo and exo generators, nitrogen and forming gas generators, gas dryers — all designed for controlled, dependable operation.



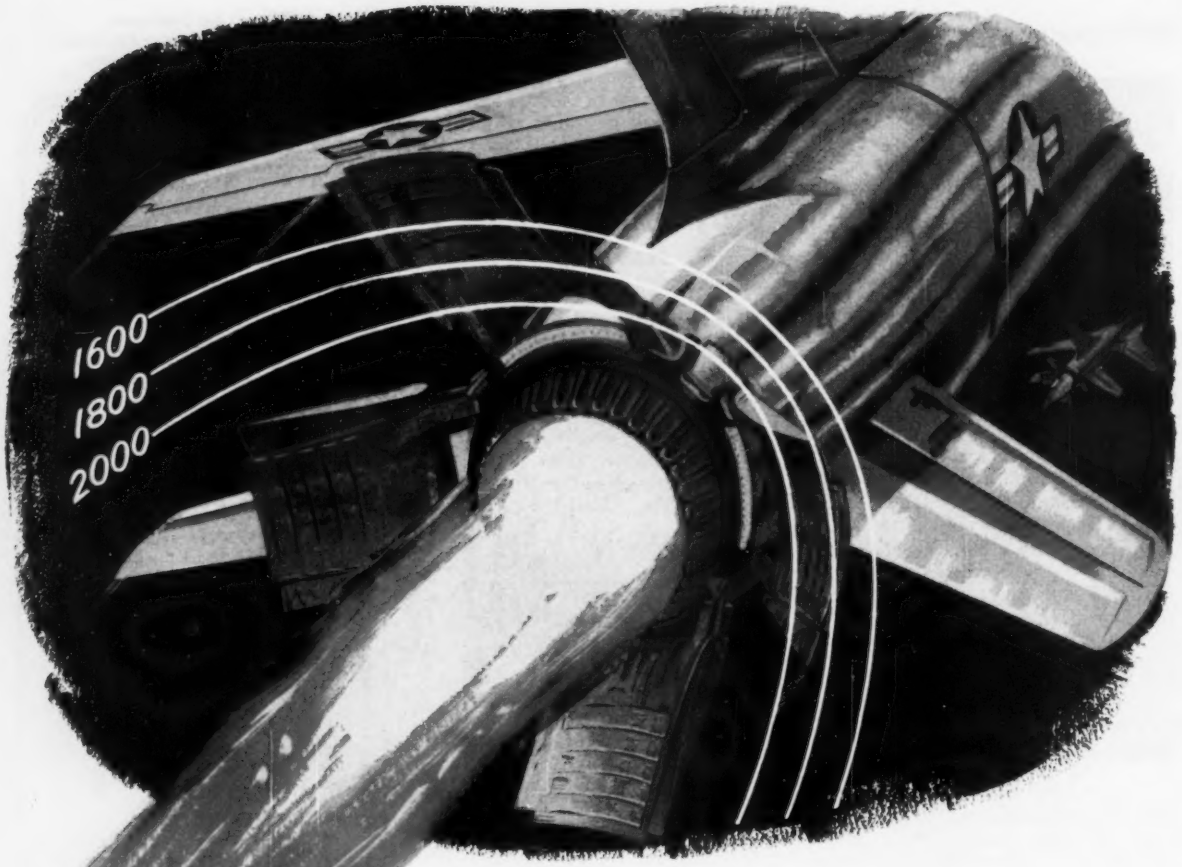
WHATEVER YOUR SINTERING PROBLEM — for production, high temperature or research sintering, Hayes know-how and equipment can supply you with a Results Guaranteed answer . . . tested in our lab on shop-scale equipment, and proved by scores of similar installations in industry. Write for bulletins on Hayes sintering furnaces. C. I. Hayes, Inc., 802 Wellington Ave., Cranston 10, R.I.

C. I. HAYES, INC.

Established 1905

It pays to see Hayes for metallurgical guidance, lab. facilities, furnaces, atmosphere generators, gas and liquid dryers, pHayes-master (TM) control units.

Circle 1079 on Page 48-B



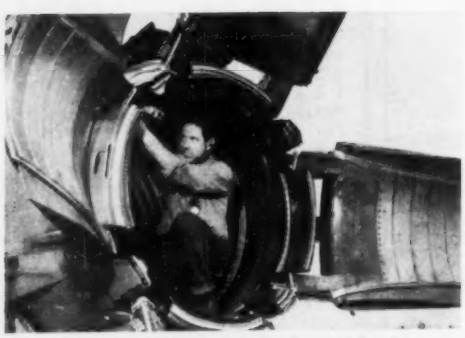
Braking 23 Tons at 1200 MPH

Few brakes are called upon to take such a beating. That's why HAYNES alloy No. R-41 was selected for all critical areas of the petal-type speed-brake on the Air Force's new F-105 Thunderchief fighter-bomber.

Closed, the tail-mounted "petals" encircle the flaming gas blast behind the J75 engine's afterburner. Then, tremendous stress loads and thermal shock are imposed as the searing-hot doors whip open into the cold airstream—to check the blazing speed of the 23-ton, Mach 2 fighter.

HAYNES high-temperature alloys that resist temperatures of 1700 deg. F and over—for long periods and under great stress—today serve many hot spots. Resistance to stress, to thermal shock, to corrosion, erosion, and fatigue, are typical properties that make these alloys so extremely useful in turbojet engines, in ramjets, missiles, rockets, manned space capsules.

Whether investment- or sand-cast, rolled, wrought, vacuum melted, or air melted, there's a HAYNES high-temperature alloy to meet your needs.



Mechanic adjusts hinge of speed-brake door whose critical parts are of HAYNES alloy No. R-41.

HAYNES
ALLOYS
HAYNES STELLITE COMPANY
Division of Union Carbide Corporation
Kokomo, Indiana

UNION CARBIDE

Address inquiries to Haynes Stellite Company, 270 Park Avenue, New York 17, N. Y.

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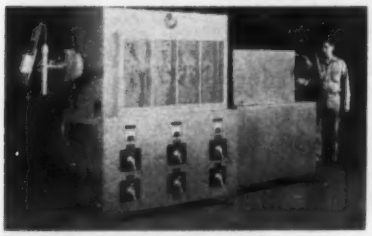
Circle 1080 on Page 48-B

inside the chamber so that all of the chamber gases are forced outside the muffle, around the U-tubes, and pulled up through the charge. The charge is transferred automatically from heating chamber to elevator to quench tank, in which recirculating oil is maintained at the correct temperature. *Johnston Mfg. Co.*

For further information circle No. 873

Zoned Tube Furnaces



Three zones of temperature control compensate for end losses in 3, 4 or 5-in. tube furnaces made by *Harper Electric Furnace Corp.* Tubular muffles in lengths from 2 to 4 ft. are furnished in porcelain (2750° F., max.) or superalloy (2300° F., max.). Suitable for firing, calcining, sintering, brazing, annealing, and general heat treating, the units can be operated as air or controlled-atmosphere furnaces. Muffles, purge chambers, and other components can be removed or replaced to meet changing research and production requirements.

For further information circle No. 874

Gas-Fired Elevator Furnace

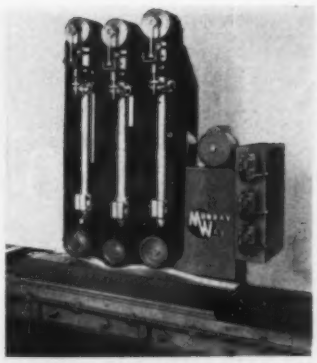
The *Harrop Precision Furnace Co.* offers two gas furnaces for a variety of applications ranging from laboratory testing to high-volume production. The "Model GF" is designed for continuous operation to 3000° F., and the high-temperature "GFHT Series" will operate continuously up to 3300° F. Furnace temperatures can be controlled manually or by instruments. Once the gas-air ratio has been set at the burners, this ratio is constant in every position. The GF series includes cabinet, elevator, and shuttle models.

For further information circle No. 875

Finishing

Multiple Grinding of Contoured Parts

Flat or contoured parts, long or short, can now be wet or dry ground from roughing to finishing in one pass on "Multiple-Float" abrasive belt heads. Each head floats independently



of the other and one motor drives all three. The rise and fall of each head is controlled by the contour of the part, or by a cam, shaped to the part contour (where closer tolerance grinding is required). Belt tracking and oscillation are controlled by an "Air-Eye" unit which automatically prevents belt run-off. Hand-operated valves allow release for quick changes. *Murray-Way Corp.*

For further information circle No. 876

Heavy-Duty Billet Grinding Wheels

The *Carborundum Co.* reports that major advances in both hot and cold pressed wheels have reduced cost per pound of metal removed from 12 to 29% in plants processing stainless steel billets. A 3-month performance record compiled in several steel plants demonstrated that hot-pressed wheels will operate well at 12,500 sfm., and cold-pressed wheels not only give superior performance on swing-frame grinders but yield a significant reduction in processing costs for mechanical grinders operating at 9500 sfm. under 450-lb. head pressure.

Circle No. 877 on literature request card

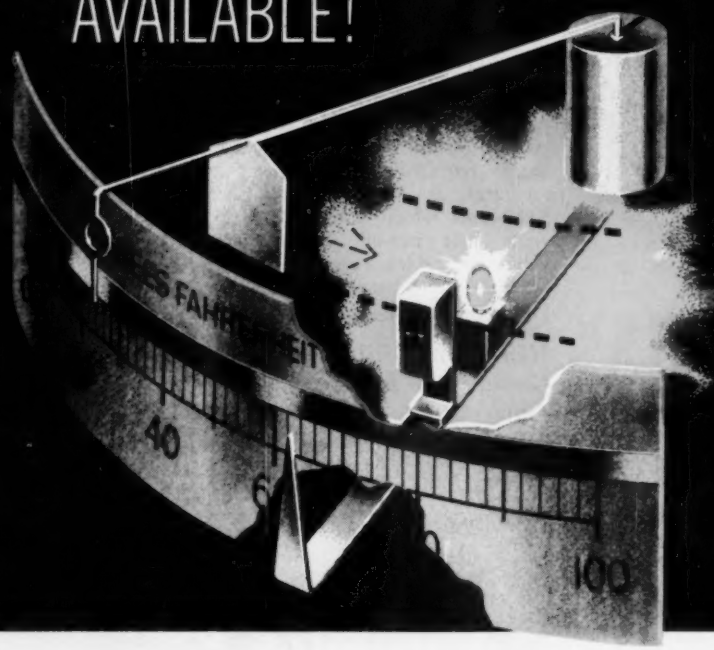
Welding

Welding Machine Converter

Sixty-second conversion of a-c. to d-c. output is possible with *A. O. Smith's* converter. Portable and self-

MINIMIZE BURN-OUT...
PSC's All-Sheet Construction Adds to Furnace Tube Life
Experience of users shows much lower frequency of burn-out, with tube life extended up to 100%. In PSC tubes, precision-welded bends are of same metal and thickness as the legs. The continuously smooth walls result in uniform flow of gas, and reduce the carbon build-up and bend burn-out, which commonly result from the rough interiors of cast alloy bends. Lighter than cast by 33 to 50%, PSC radiant tubes cost less initially. Any size, shape or alloy. We repair radiant tubes, retorts and inner covers — save you money.
PSC
THE PRESSED STEEL CO. • Wilkes-Barre, Pa.
Circle 1081 on Page 48-B

HERE'S THE MOST ADVANCED TEMPERATURE INDICATING CONTROLLER AVAILABLE!



NEW SENSITROL PYROMETER COMBINES

- **Daystrom Creative Engineering**
- **Weston Accuracy and Reliability**

The Daystrom Sensitrol Pyrometer is now available for your *most critical* temperature control applications. This new instrument has an accuracy of ±0.5%, full scale, and a sensitivity of ±0.1%, thanks to a dependable Weston galvanometer sensing element. A non-contact photocell actuates the control . . . completely eliminating drag on the galvanometer.

Here are a few of the many other features offered by Model 8800 Sensitrol Pyrometer: Solid state throughout. Plug-in modular construction for simplicity of maintenance . . . no soldering required. Only $10\frac{3}{16}$" x $7\frac{1}{2}$", the unit can be flush or panel mounted. It has a long 6-inch scale, range of 0-400 to 0-4,000 F, with set points adjustable over entire range. Signal lights at each end of the scale make it easy to read control position from a distance. Two modes—ON-OFF or three position.

Write today for complete technical data or applications assistance on the new Sensitrol Pyrometer—a product of unexcelled Daystrom experience and traditional Weston accuracy! Daystrom, Incorporated, Weston Instruments Division, 229 Manchester Road, Poughkeepsie, N. Y.

International Sales Division, 100 Empire St., Newark 12, N. J. In Canada: Daystrom Ltd., 1480 Dundas Highway East, Cooksville, Ontario.

DAYSTROM, INCORPORATED
WESTON INSTRUMENTS DIVISION
Reliability by Design

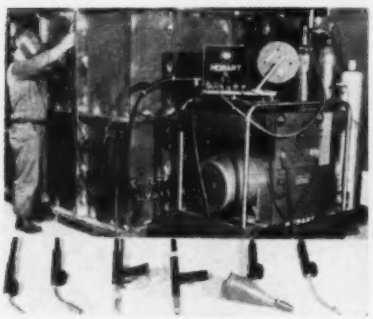
Circle 1188 on Page 48-B

contained, this silicon rectifier is available in two models: one rated 250 amp. (60% duty cycle), the other rated 450 amp. (60%). A polarity switch on the unit permits selection of desired output – straight d-c., reverse d-c., or a-c. – with no handling of leads required. When a welder contains a high-frequency unit, a simple electrical connection keeps current from damaging the rectifier.

For further information circle No. 878 on literature request card, p. 48B

Multiple Process Welder

Metal frabricators using more than one semiautomatic welding process are reducing their capital equipment investment with the "Multi-Wire" welding package, a combination welder and wire feeder. When changing from one process to another, simply attach the appropriate gun and cable assembly, drive rolls, and wire guides. The unit provides complete facilities for (*a*) small wire, all-position gas-shielding welding; (*b*) large wire CO_2 welding; (*c*) combination tubular or fluxed wire and CO_2 welding; (*d*) inert-gas-shielded metal-arc process; (*e*) hardsurfacing; and (*f*) submerged arc welding. The generator is rated 500 amp. d-c. at 40 v., 100% duty cycle. At 60% duty cycle, the machine provides 650 amp. Output voltage may be varied from 3 to 48 v. *Hobart Bros. Co.*



For further information circle No. 879 on literature request card, p. 48B

Electron Beam Welder

The "Mark VI" welder has been used successfully in welding and brazing many refractory and reactive metals, such as tantalum, columbium, titanium and beryllium. The system includes an electron gun, vacuum chamber, mechanical roughing and diffusion pumps, power supply and console. Handling fixtures inside the chamber permit spot, longitudinal, annular and circumferential welds. Controls can vary electron-gun power

AMPCO

Do you have to

COPE WITH THESE CONDITIONS?

*High heat as compared to other copper-base alloys.

AMPCO® metal

What does a copper-base alloy have to do for you? Whatever it is, there's a grade of AMPCO metal — or other Ampco alloy — that does the job exactly.

Equally important, you can select the best, most economical form of production — sand casting, centrifugal casting, shell mold, precision casting, forging, fabrication, extrusion, sheet, plate.

Call in your Ampco field engineer. Write for bulletin.

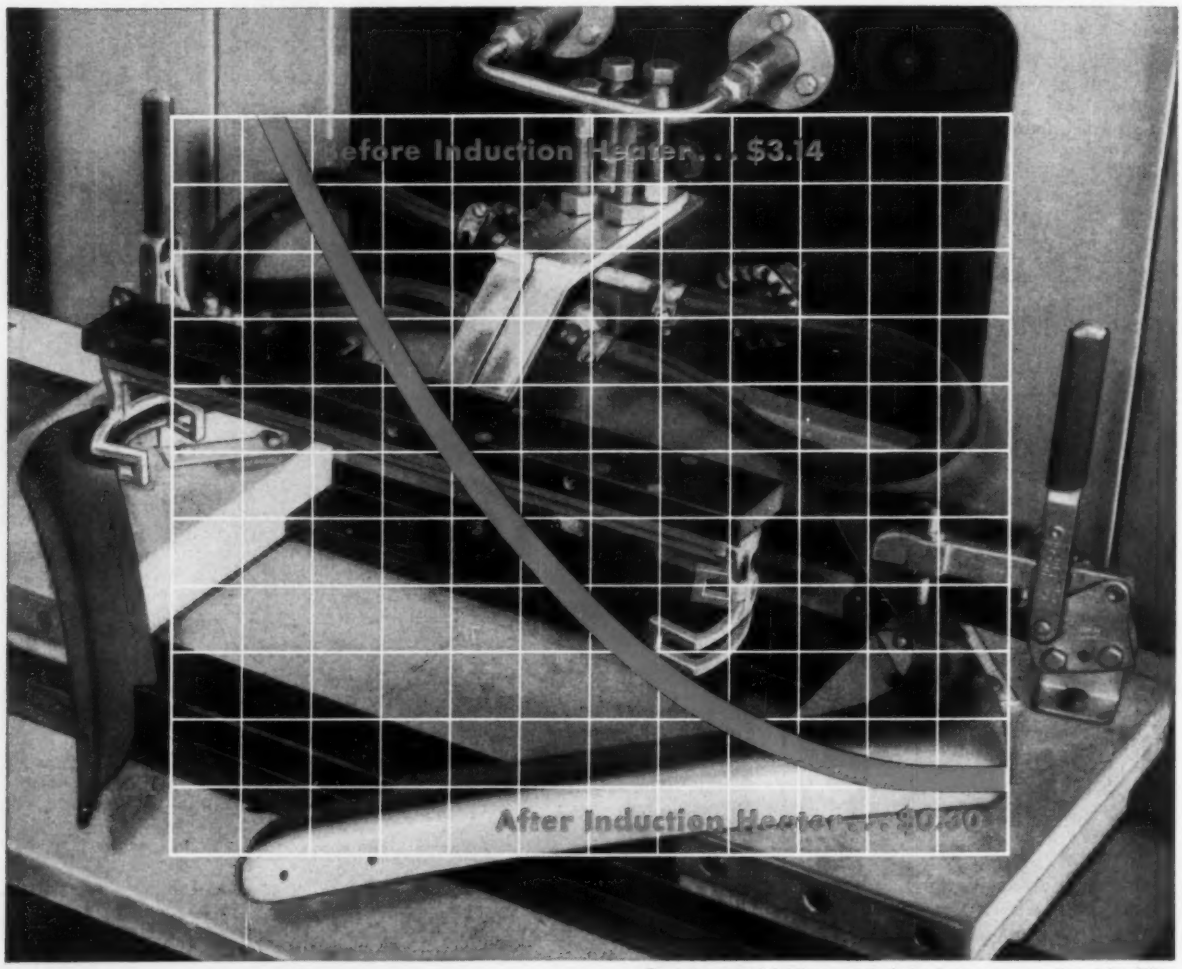
G-20C

AMPCO METAL, INC., Dept. 20 I, Milwaukee 1, Wis.

WEST COAST DIV.: HUNTINGTON PARK, CALIFORNIA • SOUTHWEST DIV.: GARLAND (DALLAS COUNTY), TEXAS

Circle 1083 on Page 48-S

ALLIS-CHALMERS



Back braces of folding metal chairs being stress relieved by Allis-Chalmers induction heater. Two-position fixture speeds production.

Allis-Chalmers induction heater replaced oxyacetylene torch

heat costs dropped 90%

One of the Midwest's leading manufacturers of metal chairs and furniture switched to an Allis-Chalmers induction heater for stress relieving of strategic parts. One of his important savings was the cost of oxygen and acetylene. Costs had been about $3.14 per hour of operation. Electric power for the Allis-Chalmers induction heater costs about 30 cents.

In addition, he has been able to increase production from 247 pieces per hour to 422 pieces. Rejects have been greatly reduced. Die life is extended because induction heat leaves no appreciable scale.

The manufacturer has reported that savings made through use of the Allis-Chalmers unit paid the total cost of the heater in six months.

Such benefits as speed, economy and convenience make Allis-Chalmers induction heaters worth your consideration for any application needing soldering, annealing, melting, brazing, hardening or forging.

Allis-Chalmers excels in larger applications — induction heaters up to 150 kw have been applied to speed up production, save labor and improve product quality. In these larger applications Allis-Chalmers points to a significant number of installations.

• • •

Let us talk with you about possible applications. Call your A-C representative. Or write, ***Allis-Chalmers,*** *Industrial Equipment Division, Milwaukee 1, Wisconsin.* A-1302

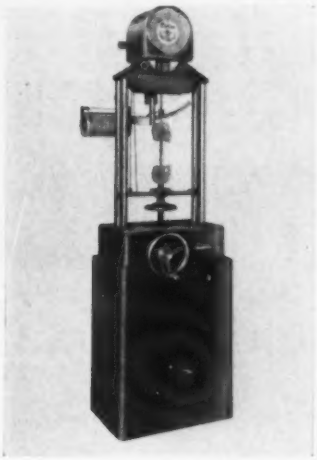
Circle 1084 on Page 48-B

supply (0 to 20 kv.; 0 to 300 milliamp.) and adjust filament, current bias, and focus. Spot diameter can be controlled from 0.010 to 0.500 in., and focal length from 4 to 12 in. *Alloyd Electronics Corp.*

For further information circle No. 880 on literature request card, p. 48B

Testing

Low-Range Convertible Head



An adapter unit from *W. C. Dillon & Co.* converts all their high-capacity models into dual-use instruments. The 8-in. dial may be either a color-coded 4-scale (0-10; 0-25; 0-50; 0-100 lb.) or a single scale, 0 to 300 lb. The adapter head is supplied in divisions of ounces, tenths of pounds, or kilograms and all dials are guaranteed accurate within ½ of 1%.

For further information circle No. 881

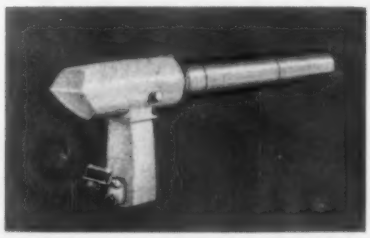
Permanent Magnet Alloy

Important requirements for permanent magnets used in motors and generators are high resistance to demagnetization and low unit-energy cost. A new alloy from *Crucible Steel Co.*, "Alnico VIII," is substantially higher than Alnico VI and VII in coercive force (1450 oersteds) and maximum energy (4.5×10^6 gauss-oersteds) and has twice the resistance to magnetization as does Alnico V. Alnico VIII, with the best magnetic stability of any permanent magnet material, is well suited to uses in magnet cores for meters, magnetic separators, focusing guns for electron-beam units, and in flat-type loudspeakers

For further information circle No. 882

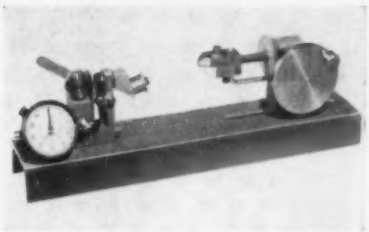
Stereomicroscope With Zoom Optics

Bausch & Lomb announces the first remote control stereomicroscope with a "zoom" optical system. Advantages include a continuous range of magnification from 1 × to 60 × and a sealing tube which permits the instrument to be repositioned at different points in a "hot" cell without danger of contamination. Shielding equivalent to 12 in. of lead protects operator from radiation. The standard model is used in a 36-in. thick wall; modifications allow installation in walls up to 60 in. thick. A 35 mm. stereo camera can be attached to it.



For further information circle No. 883

Portable Tensile Tester



A lightweight tester, "Model VTA", is available in load capacities of 50 and 100 lb. Designed for field work, the machine provides accurate tensile strength data for wire, spot-weld coupons and other small specimens. The unit, capable of testing samples from ½ to 8 in. long, has an indicator needle that locks at maximum load, and a push-button release. *Detroit Testing Machine Co.*

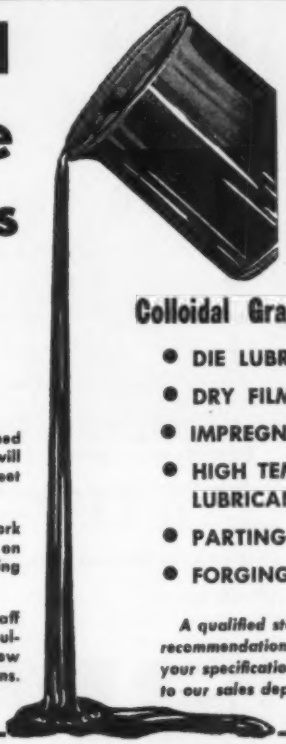
For further information circle No. 884

Colloidal Graphite dispersions

can help you

3 WAYS:

1. **Production** — For established production processes we will prepare dispersions to meet your specifications.
2. **Development** — We will work directly with your engineers on development projects requiring specialized dispersions.
3. **Research** — Our research staff is always available for consultation on new products, new processes and new applications.



Here are a few uses of

Colloidal Graphite Dispersions:

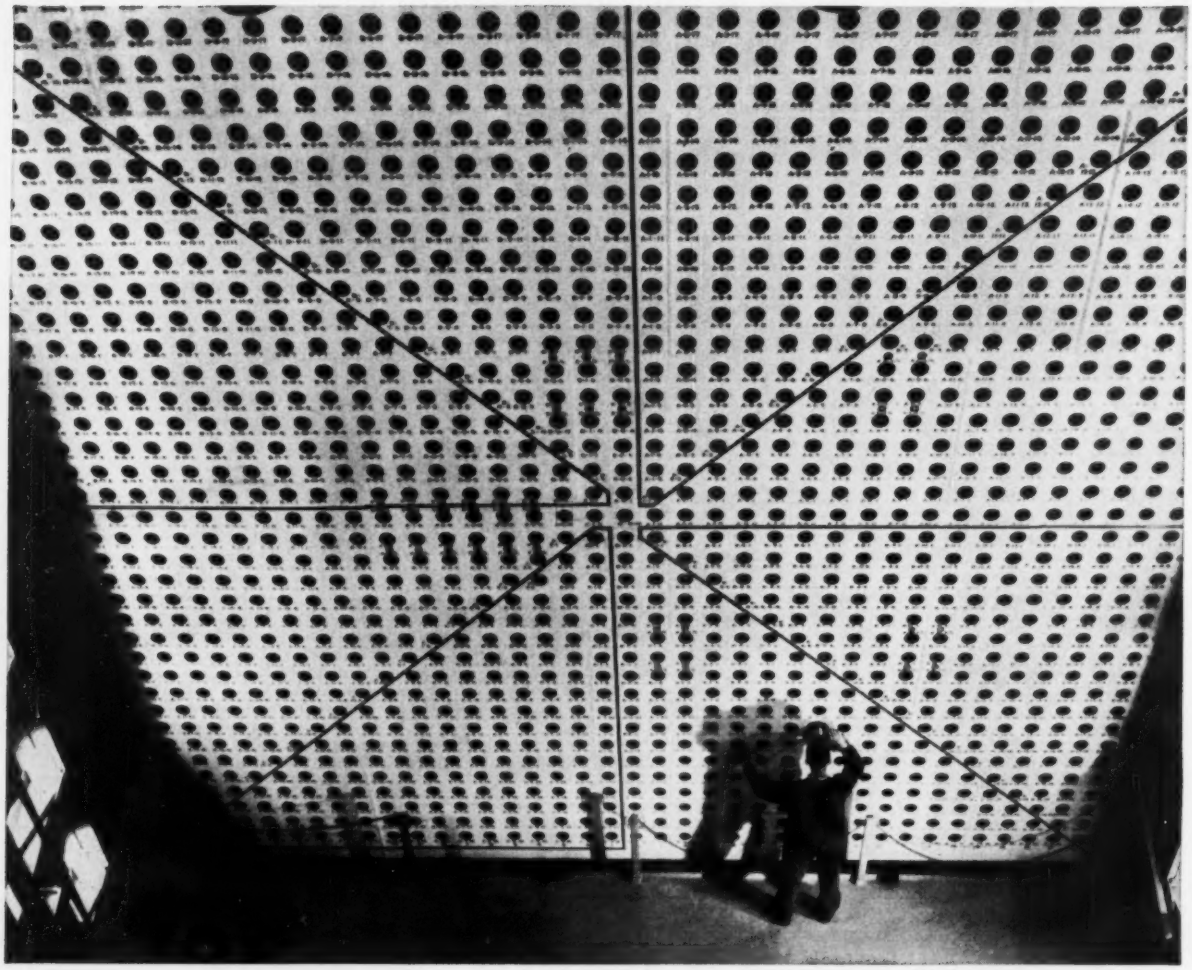
- DIE LUBRICANT
- DRY FILM LUBRICANT
- IMPREGNATING COMPOUND
- HIGH TEMPERATURE LUBRICANT
- PARTING COMPOUND
- FORGING COMPOUND

A qualified staff is available for prompt recommendations and quotations to meet your specifications or preliminary inquiries to our sales department.

GRAPHITE PRODUCTS CORP.

BROOKFIELD, OHIO

Circle 1085 on Page 48-B



PRECISE TUBING HELPS CONTROL ATOMIC REACTOR

In the intense heat and radioactivity of nuclear reactors, there are many uses for precise tubing, manufactured under rigid quality control.

This is one of the many important applications for BISHOP'S complete line of tubing up to 1 inch OD, in stainless, nickel, super and exotic alloys—and glass-to-metal sealing alloys, clad metals and composite wires.

BISHOP also produces a vast line of platinum products and chemicals.

And BISHOP is unique because of its ability to *work these metals to such small, precise forms.*

Write for Bulletin No. 12, tubular products; or Catalog No. P-6, platinum products.

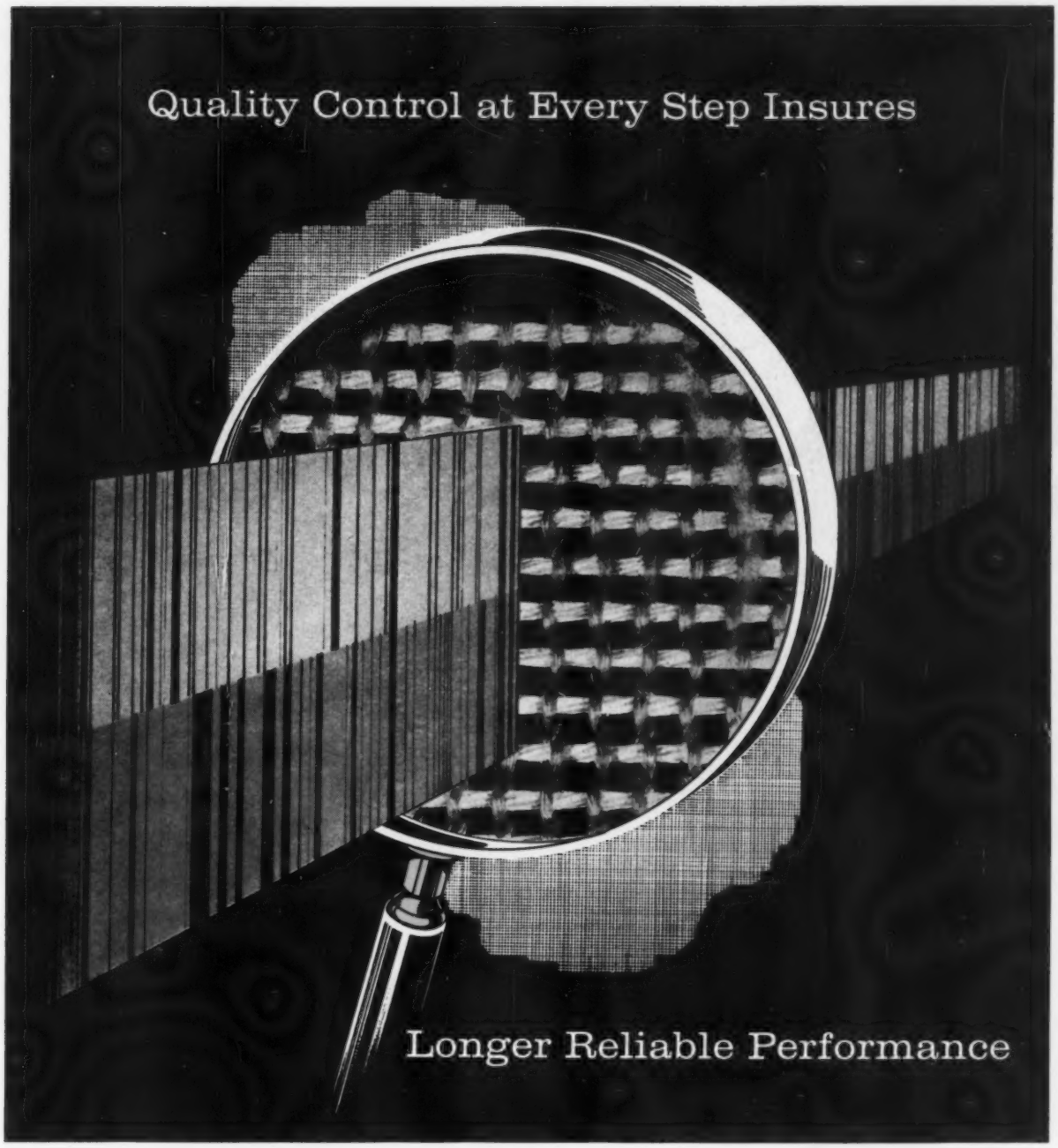
BISHOP

Tubular Products Division **J. BISHOP & CO.** *platinum works* MALVERN, PENNSYLVANIA

A JOHNSON MATTHEY ASSOCIATE "METALS FOR PRECISION AND PERFORMANCE"

OFFICES: NEW YORK • PITTSBURGH • CHICAGO • ATLANTA • HOUSTON • LOS ANGELES

Circle 1086 on Page 42-B



NORTON REFRACTORY CEMENT

The quality of any high purity metal can only be as good as the quality of the refractory cement used to contain it. That's why Norton is producing cement that is uniformly quality controlled — *in each separate phase of its processing* — both physically and chemically.

Norton Refractory linings give more heats and closely predictable performance from lot to lot. The optimum density of Norton Cements gives them the mechanical strength to withstand the highest operating temperatures without spalling, slumping or otherwise failing — and to resist stresses imposed during charging, pouring and cleaning.

Norton engineers are prepared to formulate refractory cement to satisfy your individual metallurgical requirements. You'll get greater economy with Norton Cements because they retain their effectiveness longer and eliminate much of the patching required by grades of lower quality. Take advantage of this new idea in quality-controlled, custom-formulated cements that can help produce a better end product for you. For details on ALUNDUM* aluminum oxide, MAGNORITE* magnesium oxide, spinels and CRYSTOLON* silicon carbide cements, write today to NORTON COMPANY, Refractories Division, 328 New Bond Street, Worcester 6, Mass.

*Trade Marks Reg. U. S. Pat. Off. and Foreign Countries

NORTON
REFRACTORIES
Crystallizing ideas into products

Circle 1087 on Page 48-E

Another vital new concept in chemical pre-paint treatment by AMCHEM!
ROLL COAT APPLICATION OF ALODINE* FOR PRE-TREATING ALUMINUM!

Now, Amchem further widens pre-paint treatment flexibility! First there was spray application, then dip, then spray-dip — all exclusive Amchem developments. And today, Amchem announces *roll coat application* of chromate coatings, providing still more features and economies in treating aluminum!

Roll coating with Alodine offers greater flexibility in processing and in speed, in cost reductions for maintenance. Equipment required is minimized. Uniformity of coating is equal to or better than existing methods. Advanced equipment design and increased chemical activity of Alodine 1200 Series chemicals make roll coating possible. It is the most practical and efficient pre-treating process yet available for aluminum fabricators.

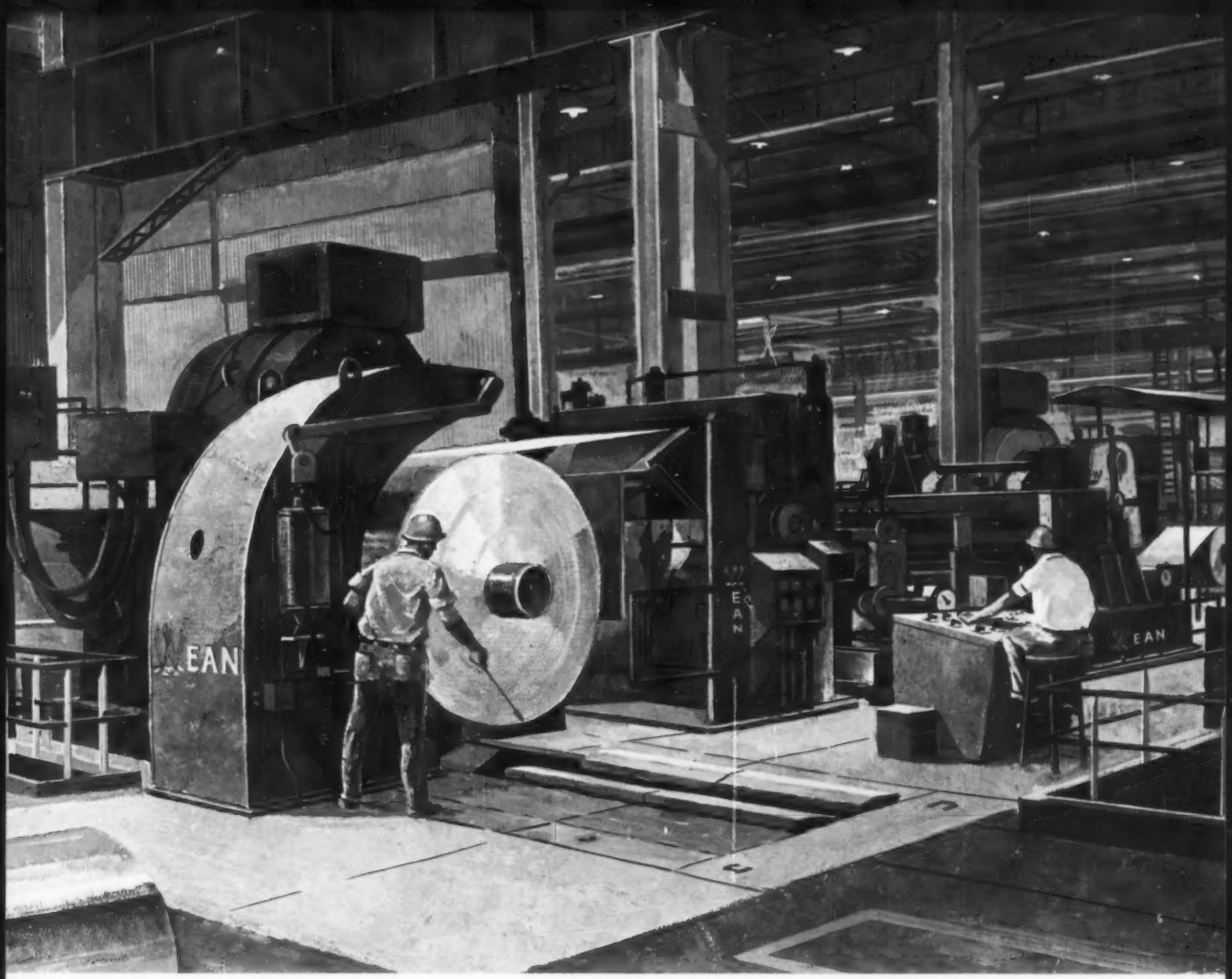
Get the full details on how roll coating with Alodine can save you substantial time, money and labor while boosting product quality through the ultimate in paint adhesion. Call your local Amchem Representative, or write us direct, but do it soon!

*Amchem's registered trademark for its conversion-coating chemicals for aluminum.

AMCHEM **ALODINE**

Amchem is a registered trademark of
AMCHEM PRODUCTS, INC. (Formerly American Chemical Paint Co.)
AMBLER, PA. • St. Joseph, Mo. • Detroit, Mich. • Niles, Calif. • Windsor, Ont.

Circle 1088 on Page 48-B



PORTRAIT OF PROGRESS: *Wean Coil Preparation Line at Weirton Steel Company, Division of National Steel Corporation*

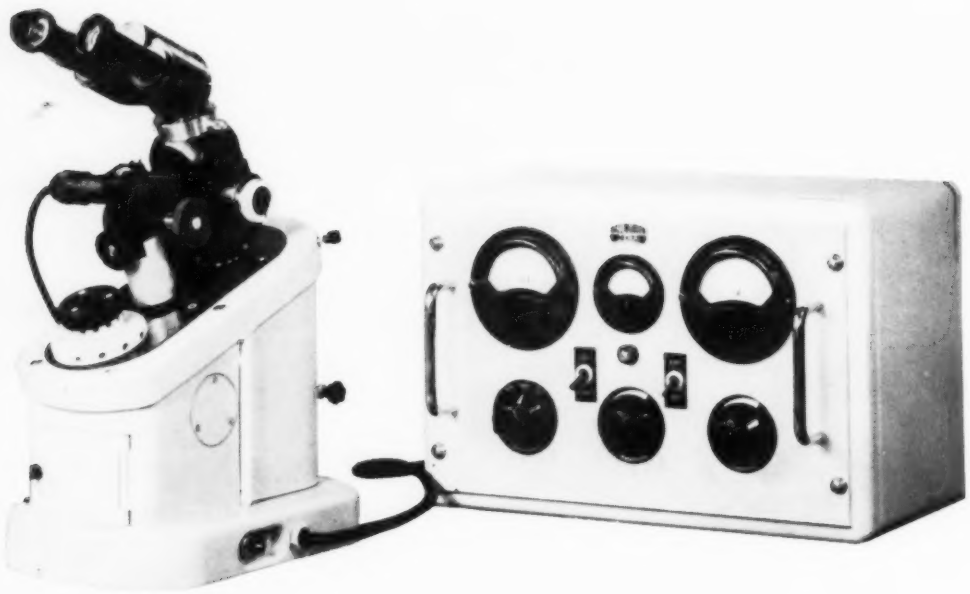
Weirton Increases Efficiency of Tinning with Wean Coil Preparation Line

The trend toward purchase of tin plate in coil form has placed increased emphasis on the production of uniformly high quality coils. To assure this uniformity in the end product, Weirton Steel Company has installed this high-speed Wean side-trim and recoil line to prepare coils for the tinning operation. The line side trims tin plate stock and builds up larger, more evenly wound coils for more efficient operation of the tinning lines.

This tension-type line has a maximum speed of 4,000 fpm and is able to handle 60,000 lb. coils 18″ to 45″ wide. Maximum inside diameter of the coils is 16½″; outside diameter, 85″.

More efficient continuous coil processing has been the primary goal of Wean's engineering research for over 30 years. Why not use modern Wean technology to help you in increasing the efficiency of your continuous processing facilities.

THE WEAN ENGINEERING COMPANY, INC. · WARREN, OHIO



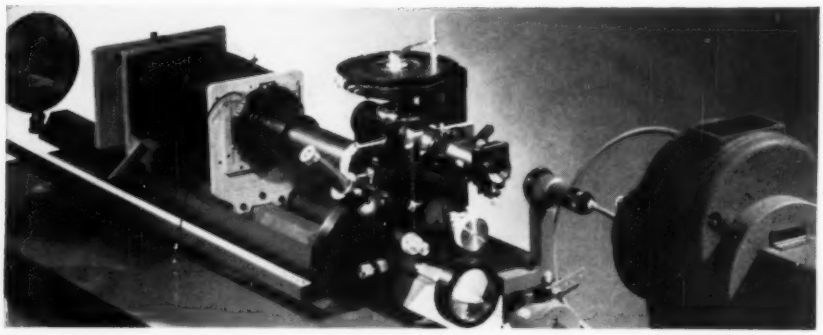
CARL ZEISS JENA

companion of scientific progress for six generations

ELECTROLYTIC POLISHER

The Carl Zeiss Jena Electrolytic Polisher is the only instrument in the world permitting constant observation of the etching process. Elimination of stop-and-start, trial-and-error specimen preparation results in tremendous time saving and increased accuracy.

- Electrolytically removes layers from specimen surface under controlled conditions
- Polisher is completely closed during operation protecting user from contact with electrolyte or live electrical parts
- Automatic safety interlock stops electrolytic action when unit is opened
- Specimen size up to 30 mm. high x 100 mm. diameter
- Microscope provides 210X magnification
- Easily adaptable to photomicrographic studies
- External power supply unit included



NEOPHOT–Research Metallographic Microscope

Modern, incident-light, photo-microscopy has a strong ally in the Carl Zeiss Jena Neophot, an extremely accurate research metallograph priced as a routine instrument.

- Optical system corrected to produce highest resolution and flatness of field obtainable
- Highly flexible . . . bright field, dark field, polarization, phase contrast
- Three individual photographic systems permit a succession of imaging scales from 0.5:1 to 1600:1
- Microhardness Tester (model D32) available as accessory unit

Complete information may be obtained from your local Carl Zeiss Jena instrument dealer or by writing: Dept. MP 9/61

ERCONA Ercona Corporation, Scientific Instrument Division, 16 West 46th Street, New York 36, N.Y.
In Canada: Jena Scientific Instruments Ltd., 1437 MacKay Street, Montreal, Quebec

Circle 1089 on Page 48-B

Why GRAPH-MO® steel makes better gages and dies, cuts cost, too

The master plug gage in the illustration above showed less than 10 millionths of an inch change after twelve years of use. It's made of Graph-Mo®, one of the family of Timken tool steels—the most stable steels you can buy.

In addition to its great stability, Graph-Mo wears longer. As a matter of fact, users report it outwears other ordinary steels 3 to 1. This is because of the combination of free graphite particles and diamond hard carbides in its structure.

And you save money with Graph-Mo. A special oil-hardening tool steel, it machines faster and easier than ordinary steels. As a result, machining time and production costs are reduced.

When you buy Timken steel you get... *1) Quality that's uniform from heat to heat, bar to bar, order to order. 2) Service from the experts in specialty steels. 3) Over 40 years experience in solving tough steel problems.*

All these advantages are yours at no extra cost. Graph-Mo costs no more than other oil hardening tool steels. And remember, there is only one Graph-Mo. The Timken Company makes it.

The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable: "TIMROSCO". *Makers of Tapered Roller Bearings, Fine Alloy Steel and Removable Rock Bits.*

TIMKEN GRAPHITIC STEELS ARE AVAILABLE FROM STEEL SERVICE CENTERS IN 44 CITIES IN THE UNITED STATES AND CANADA

Circle 1090 on Page 48-B

THE NEW

POWERMET PRESS

FOR THE MOST RAPID MOUNTING OF METALLURGICAL SAMPLES

- PUSH BUTTON CONTROLLED
- POWER OPERATED
- SELF CONTAINED HYDRAULIC SYSTEM
- CONTROLLED MOLDING PRESSURE
- USE PREMOLDS OR POWDER
- BAKELITE OR TRANSOPTIC MOUNTS
- PRODUCES 1", 1¼", or 1½" MOUNTS
- BAYONET TYPE MOLDS
- THERMOSTATICALLY CONTROLLED HEATERS
- QUALITY COMPONENTS USED
- CONFORMS TO J.I.C. STANDARDS

Buehler Ltd.

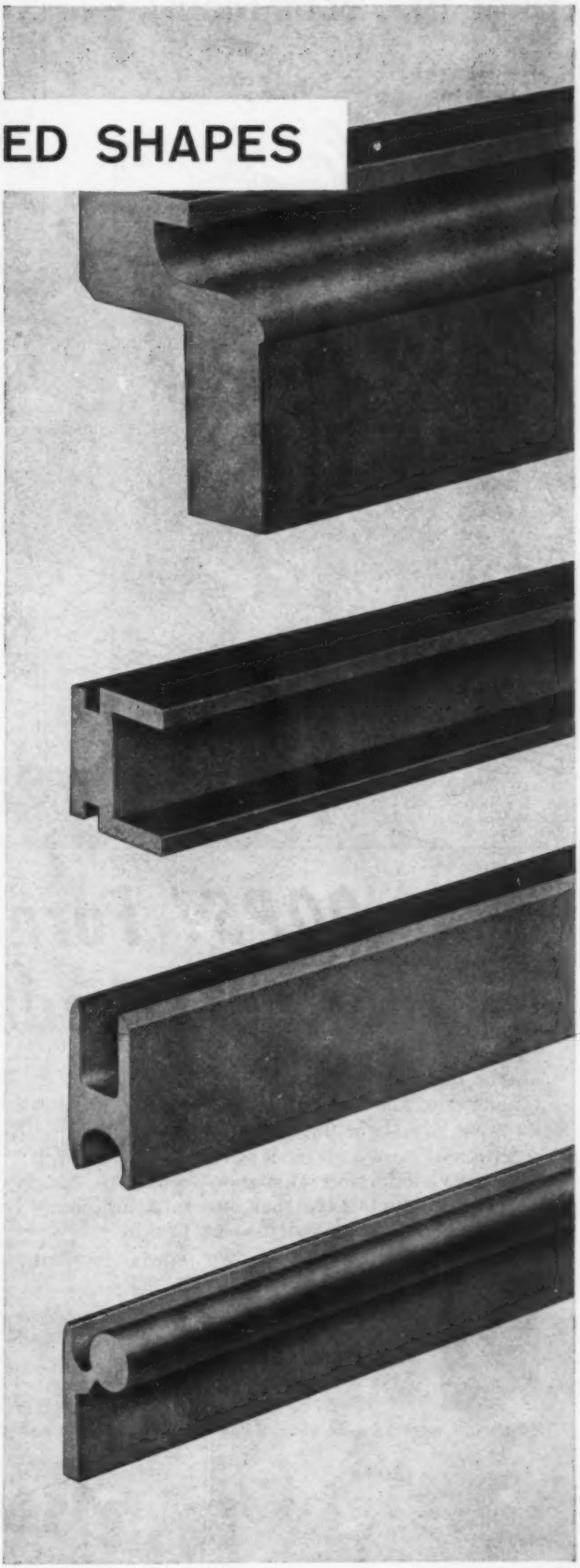
METALLURGICAL APPARATUS

2120 GREENWOOD ST., EVANSTON, ILLINOIS, U.S.A.

ANACONDA EXTRUDED SHAPES

preformed to cut fabricating costs

...preferred for superior quality!



Would you like to reduce machining, scrap, and finishing by *cutting* parts from long lengths of extruded shapes?

Anaconda shows you how . . . by designing long lengths of "pre-machined" shapes exactly suited to the parts you need. Parts made from these extruded brass shapes are characterized by their strong, homogeneous, wrought-metal structure. They are superior, long-wearing parts that *improve* the quality of your finished product. What's more, the smooth, extruded surfaces also reduce many finishing operations —additional savings for you.

Discover why more and more manufacturers are cutting fabricating costs and maintaining better quality by using these preformed shapes. Let our technical service personnel lend practical—and imaginative—help in adapting extruded shapes to the economical production of intricate parts.

Call your Anaconda representative or write: Anaconda American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario. 61-1063

EXTRUDED SHAPES

ANACONDA®
AMERICAN BRASS COMPANY

Circle 1092 on Page 48-B

OOPS! Furnace down! Pouring schedule imperiled!

Maybe our cartoonist exaggerated the effect of this news on the Inductotherm offices, but at least he gives you the general idea.

Trouble doesn't often develop in Inducto high frequency induction furnaces. When it does, however, Inductotherm believes in doing something constructive about it—and pronto!

Here, in the customer's own words, is what happened:

"Inductotherm's 24-hour service saved our casting schedule,"

says SAM MINIEA, President, Truecast Precision Casting Corporation, Louisville, Kentucky.

"We were working a 24-hour, 7-day week schedule when our only melting furnace started delivering only half power. A hurried call to Inductotherm brought an engineer to our plant Saturday morning to diagnose and repair trouble in a loose rheostat brush. Thanks to this service expensive down-time was less than 24 hours."

Helpfulness on melting problems and the promptest kind of service to large and small customers alike is a big part of Inductotherm's concept of doing business—that plus a complete line-up of the finest kind of furnace equipment we know how to build. And it all adds up to saving you money. For the entire story, why not talk with an Inducto furnace engineer soon! Inductotherm Corporation, 10 Indel Avenue, Rancocas, New Jersey.

INDUCTOTHERM

Subsidiary for 60-cycle melting equipment—INDUCTOTHERM LINEMELT CORP.

Circle 1093 on Page 48-B

NEW LITERATURE

Steel

889. 17-4 PH Stainless

Armco Steel Corp. has published data on 17-4 PH stainless steel; stronger than Type 416, with corrosion resistance in the 18-8 class.

890. Tool Steel Selector

The *Allegheny Ludlum* tool steel "Steelector" booklet contains selector cards, descriptions of the various tool steel grades, and explains individual "Data Stock lists" available for each grade.

891. Alloy Steel Booklet

"Quick Facts About Alloy Steels", published by *Bethlehem Steel Co.* Elementary information on steel heat treatment, properties, and microstructures.

892. Stainless Steel

Catalog "*Armco* Stainless Steels" discusses applications for stainless sheet, strip, bar, and wire in 60 analyses and a broad range of sizes and finishes.

893. Austenitic Stainless

8-p. booklet explains nature and occurrence of sigma phase, as well as its chemical composition, identification, and effect on mechanical properties and corrosion resistance. *Electric Steel Foundry Co.*

894. PH Steels

Republic Steel Corp. offers literature on 17-7 PH and PH 15-7 Mo stainless steels for improved properties and formability.

895. Strippable Plastic

Plastic film protects stainless steel surfaces during handling and fabrication. *Washington Steel Corp.* will send complete details.

896. Seamless Tubing

Ohio Seamless Tube Div. has released pamphlet on seamless and electric welded tubing for mechanical, aircraft and pressure applications.

897. Low-Alloy Steel

Bulletin 36B from *Timken Roller Bearing Co.* details the advantages of "17-22-A" steels which give high-alloy performance at low-alloy cost.

898. Vacuum Melting

Consumable-electrode melted steels are cleaner and segregation and variation in grain size are minimized. Information from *Carpenter Steel Co.*

899. Free-Machining Stainless

Brochure entitled "Uniloy 303MA" discusses characteristics and properties of free-machining Type 303 stainless. *Universal-Cyclops Steel Corp.*

900. Cold Finished Bars

Information from *Republic Steel Corp.* on "Century 100 Series" cold finished bars, available in five grades, five degrees of machinability and five price levels.

901. Tool Steels

Uddeholm Co. of America will send leaflet on "UHB Orvar" (S.A.E. H13), a hot-work tool steel with excellent heat-checking, nondeforming and nonscaling properties.

902. Precipitation-Hardening Stainless

32-p. booklet from *Republic Steel Corp.* contains data on heat treatment, chemical properties, fabricating characteristics and applications for all precipitation-hardening stainless steels.

Nonferrous

904. Zirconium Products

"Zirconium Data File" gives information on production of zirconium and hafnium smelting, wrought products, alloys and properties, fabrication, and applications. *Carborundum Metals Co.*

905. "Handbook of the Alloyist"

Discusses advantages of several groups of alloys used in the electrical and electronics industries. Properties and typical applications are given. *H. K. Porter Co.*

906. Molybdenum Sheet

A.S.T.M. reprint presents data on properties and applications of molybdenum-base sheet. *Climax Molybdenum Co.*

907. Nickel Alloys

International Nickel Co. has application data and engineering information on nickel, its alloys, and the various grades of stainless for unusual conditions of stress, fatigue, heat or cold, or corrosion.

908. Cobalt and Nickel-Base Alloys

4-p. data sheet lists physical and mechanical properties, corrosion resistance, thermal treatments, fabricating data, available forms, and applications of 13 alloys. *Cobalt Information Center.*

909. Aluminum-Lithium Alloys

Report 4073 on the physical and mechanical properties of some aluminum-lithium alloys has been issued by *Lithium Corp. of America, Inc.*

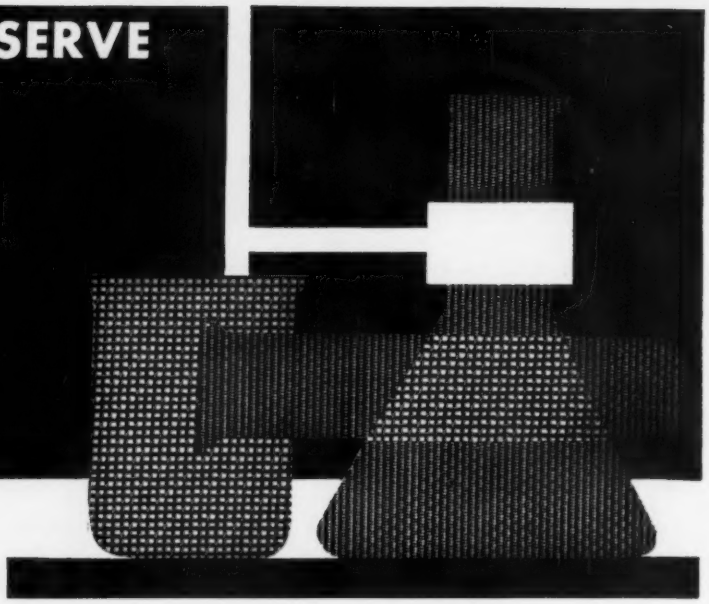
910. Ductile Vanadium

Vanadium Corp. of America has published "Ductile Vanadium: Techniques That Make Fabrication Easier", which discusses new fabricating techniques for hot worked and cold worked ductile vanadium including annealing range, extruding methods, machining and welding.

Circle appropriate number on Reply Card, p. 48-B

use wire cloth in critical operations?

THEN THEY DESERVE *Cambridge* WIRE CLOTH QUALITY & SERVICE



What is Cambridge Quality?

Wire that consistently meets metal or alloy analyses. Trained operators and modern looms to produce cloth from any metal or alloy in any weave. Constant inspection to assure high accuracy in mesh count and mesh size. Craftsmen to make fabrications in any size, shape or quantity to exacting specifications.

This is Cambridge Wire Cloth Quality.

What is Cambridge Service?

Prompt answers to mail or phone inquiries. Experienced Field Engineers—experts in their field—who can help you select the wire cloth to do the best job at lowest cost. Prompt deliveries. Large stocks of frequently used cloth for immediate shipment. Follow-up service to see that our product is giving you the results you want.

This is Cambridge Wire Cloth Service.

Your Cambridge Field Engineer can show you how Cambridge quality and service can help you in your operation. Call him at any time. He's listed in the Yellow Pages under "Wire Cloth". Or, write direct for illustrated 120-page catalog.

Refer to our technical data sheet in CHEMICAL ENGINEERING CATALOG, Page 185.

The Cambridge Wire Cloth Co.

Department B • Cambridge 9, Maryland

Manufacturers of Metal-Mesh Conveyor Belts, Flat Wire Conveyor Belts, Wire Cloth, Wire Cloth Fabrications and Gripper ® Metal-Mesh Slings.

Circle 1094 on Page 48-B

911. Machining Aluminum

Leaflet prepared by *Reynolds Metals Co.* presents data on machining speeds, recommended coolant-lubricants, tool materials and setups; also lists alloys with best machinability.

912. Aluminum Casting Alloy

8-p. bulletin introduces a high-strength shock-resistant casting alloy, "Precedent 71" similar in characteristics to Almag 35. *William J. Jobbins, Inc.*

913. Tin News

The Malayan Tin Bureau offers free subscription to their publication, a monthly bulletin on tin supply, prices, and new applications.

914. "More Zr Facts"

Bi-monthly published by *Carborundum Metals Co.* presents physical, nuclear and mechanical properties as well as fabrication techniques for zirconium and its alloys.

Materials

916. Inconel Alloy

Technical Bulletin T-7 sets forth the details on Inconel, a nickel-chromium alloy with outstanding corrosion resistance and good high-and-low temperature properties. *Huntington Alloy Products Div.*

917. Space-Age Ceramics

The *Coors Porcelain Co.* has released literature discussing the "Rokide Process" for producing oxide coatings on the surface of metals to withstand high-temperature environments.

918. René 41

Technical Bulletin No. 86 discusses René 41, the most dependable alloy in use today in the 1200 to 1800° F. range. *Cannon-Muskegon Corp.*

919. Thermal Fatigue

Electro-Alloys Div. will send you a report entitled "The Mechanism of Thermal Fatigue", by H. S. Avery.

920. Corrosion Data Charts

The corrosive effects of 400 different materials on 16 different alloy systems—including Hastelloys, Monel, nickel, Inconel, aluminum, tantalum, titanium and zirconium—are shown in data chart published by *Nooter Corp.*

921. Refractory Metal Chart

Offered by *Fansteel Metallurgical Corp.* Lists the properties of the refractory elements tungsten, tantalum, molybdenum, and columbium.

922. High-Temperature Alloy

16-p. booklet discusses "Haynes Alloy 56", a lower-cost, high-temperature alloy with good strength and oxidation resistance in the 1200 to 2000° F. range. *Haynes Stellite Co.*

923. 1800 to 2300° F. Service

"Supertherm" is a 26% Cr, 35% Ni alloy stabilized with cobalt and tungsten. Application information and other details available from *Electro-Alloys Div.*

924. Diffusion Coatings

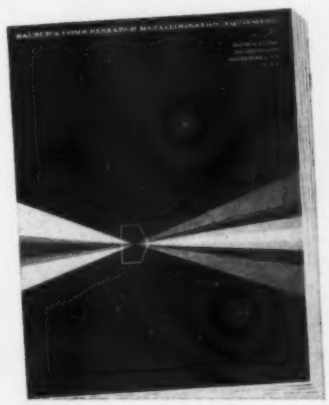
Folder from *Haynes Stellite Co.* discusses diffusion coatings—hard, nonporous surfaces for metals and alloys which increase oxidation resistance at temperatures to 2300° F.

925. Ceramic Coatings

The *Norton Co.* will send complete details on "Rokide" coating process, an economical way to protect parts and equipment against extreme abrasion and temperatures to 4600° F.

888. Metallographic Equipment

Written for today's expanding metals industry, a comprehensive brochure on metallographic equipment is of special interest to metallurgists because of a series of outstanding photomicrographs illustrating capabilities of these research instruments. The publi-



cation emphasizes the thoroughness and versatility of metallographs in providing effective results with bright field, dark field and polarized light for both visual observation and photomicrography. Accessories, eyepieces, and objectives are also described. *Bausch & Lomb Inc.*

926. Molecular Bonding

The molecular bonding process is described in 12-p. leaflet from *Al-Fin Corp.* Aluminum can be bonded to low-carbon or alloy steel, Kovar, cast iron, molybdenum or stainless steel.

927. Tungsten and Molybdenum

General Electric Co. has prepared brochure on properties and applications of tungsten and molybdenum.

928. Arc Crystal Tungsten

Linde Co. will send details on arc crystal tungsten — ingot of crystal bar tungsten melted in arc furnace — which possesses unusual ductility and high degree of workability.

929. High-Alloy Casting

Bulletin G-261 discusses applications for high-alloy castings in the 1800 to 2200° F. range. *Duraloy Co.*

930. Diamond Knives

DuPont will send information on diamond knives . . . unusually fine edge quality.

931. Chromallizing

This process diffuses one or more elements into the surface of steels, superalloys, or refractory metals to protect them from oxidation at high temperatures. Information from *Chromalloy Corp.*

932. "Design & Application Technics"

6-p. magazine, published four times a year, covers development, design, production and application of products and materials made by the company. *U.S. Graphite Co.*

933. Prealloyed Stainless Powders

Vanadium-Alloys Steel Co. has issued leaflet describing properties and applications of "Vasco 304 and 316" stainless steel powders.

934. Refractory Materials

Booklet from *Norton Co.* describes many refractory materials employed in applications such as protecting rocket engines, handling molten metals, or in chemical processing.

935. Boron Nitride

Brochure from *Carborundum Co.* discusses characteristics of boron nitride; easily machined and resists high temperatures and corrosion.

936. Heat-Resistant Castings

International Nickel Co. offers 64-p. booklet "Heat Resistant Castings, Corrosion Resistant Castings . . . Their Engineering Properties and Applications".

937. Mo and W

Pressed and sintered tungsten or molybdenum ingots up to 10 in. in diameter and up to 4 ft. long are available from *Sylvania Electric Products.*

Tooling

939. Slide-Rule Calculator

Latrobe Steel Co. will send you a slide rule price estimator and weight calculator for the company's line of high-speed tool steels and die steels.

940. Tool Steel Guide

Written by B. L. Averbach of M.I.T., "Tool Steels", a basic guide to the use of tool and die steels, has been published by *Climax Molybdenum Co.*

941. Tool Steel Identification

The *Gorham Tool Co.* has published their ninth edition of a 26-p. booklet covering classifications and symbols for identification of high-speed steels.

942. Machining of Metals

16-p. engineering report, "A Yield Criterion Applied to the Shear-Angle Relationship", by B. N. Colding, is available from *Cincinnati Milling Machine Co.*

943. Turks Heads

Fenn Mfg. Co. has prepared a booklet detailing applications, size control, surface finish, pull-through power sources, wire-shaping mills, and case histories on actual installations.

944. Cast Cutting Tools

Vascoloy-Ramet Corp. will send booklet covering applications for "V-R Tantung", a cast alloy for cutting tool and wear applications.

945. Automatic Gage Control

Flyer from *General Electric*, GEA-7224, describes control system for cold-strip steel rolling mills which utilizes x-ray sensing gages and static "Directo-Matic" control to keep the strip on gage automatically.

To request any item listed circle appropriate number on Reply Card, p. 48-B

Baskets cast of HT high-nickel alloy give outstanding performance at 1700° F

These baskets carry metal parts through a malleabilizing cycle of 45 to 50 hours at 1600-1700° F.

They're cast of Type HT* nickel-chromium-iron alloy to obtain excellent strength and ductility. These properties, combined with this high-nickel alloy's outstanding resistance to oxidizing atmospheres, result in long service life and dollar-saving economies.

Type HT high-nickel alloy, with its heat resistance and good strength—with its casting ease and economy—proves time and time again to be an ideal choice for furnace baskets, trays and other load-bearing members used in heat treating furnaces.

Wide range of alloys. Type HT alloy is just one of a family of five austenitic casting alloys available for heat treating service. Each—thanks to its high alloy content—provides outstanding resistance to thermal fatigue and most furnace atmospheres.

In this family of high-nickel alloys, you'll find metals that provide good strength and long life at temperatures from 1200 to 2300° F. You'll find alloys with remarkable combinations of properties—properties needed to withstand oxidizing and reducing environments and carburizing and nitriding atmospheres.

Which heat-resisting alloy is best for your needs? You'll find the answer in the 72-page booklet, "Heat Resistant Castings, Corrosion Resistant Castings ... Their Engineering Properties and Applications." Write Inco for your copy today.

*A.C.I. designation.

THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street New York 5, N. Y.

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

946. Collodial Dispersions

When excessive temperatures, pressures, or abrasion are encountered colloidal graphite dispersions make forging, extruding or die casting operations easier, smoother and better. *Grafo Colloids Corp.*

947. Carbide Tools

50-p. catalog and price list on "Coromant" tungsten carbide tools and inserts has been published by *Sandvik Steel, Inc.*

948. Process Lubricant

Bulletin 26 details the advantages of "Fleximet S", a multipurpose lubricant for dry drawing and hot dip-dry coatings. *Swift & Co.*

Heating

950. Heat Treating Costs

Pittsburgh Commercial Heat Treating Co. has released a booklet "The Cost of Heat Treating" which will assist companies now doing their own heat treating to establish the cost of this operation.

951. Heat Treating Chart

Tempil Corp's four-color chart, "Basic Guide to Ferrous Metallurgy," illustrates forging, burning, annealing, transformation, stress relieving, nitriding, blue brittle, normalizing, and carburizing ranges, as well as grain size changes vs. temperature.

952. "Heat Treat Review"

Contains discussion of new developments in high-temperature gas carburizing, including heating curves, photomicrographs of test samples, and illustrations of carburizing equipment (Vol. 11, No. 2). *Surface Combustion Div.*

953. Induction Heating

56-p. catalog from *Induction Heating Corp.* presents complete line of induction heating equipment for hardening, brazing, soldering, forging, annealing, melting, sintering, welding, refining, shrink fitting, and crystal growing.

954. Induction Heating

Ohio Crankshaft Co. has released pamphlet discussing "Typical Results of Tocco Induction Heating for Forging and Forming".

955. Open Coil Processs

Open up the steel coil and subject it to controlled gases, and you can produce commercial quantities of "direct-on" enameling steel from regular rimmed steel sheet. Bulletin OC-960 from *Lee Wilson Co.*

956. Temperature Controls

Minneapolis-Honeywell has released a leaflet discussing a "Model T444" control for a wide variety of industrial applications requiring independent high-temperature and low-temperature settings and switching action. Ranges from 0 to 660° F.

957. Graphite Elements

Graphite heating elements for resistor furnaces performing up to 3000° C. provide excellent thermal, electrical, and mechanical advantages. *National Carbon Co.* will send data.

958. Silicon Carbide Element

Leaflet from *Carborundum Co.* describes "Globar" silicon carbide heating element for precise, economical electric heating.

959. Bright Annealing

The *Electric Furnace Co.* has released a publication describing equipment for bright annealing of stainless strip.

960. Flame Heating

"Flamatic" building block design lets you purchase standard units that can be assembled into a flame heating machine tailored to your operation. Details from *Meta-Dynamics Div.*

961. Fluidized Bed

Alexander Saunders & Co. has released pamphlet discussing applications and operating details of "Saunders" fluidized-bed furnace.

962. Infrared Equipment

4-p. leaflet describes high-intensity infrared equipment with extremely high heat transfer rates. *Fostoria Corp.*

963. High-Temperature Controls

Design catalog sheet covers "Type E36N" indicating temperature control. *United Electric Controls Co.*

964. Electric Ovens

240-p. Catalog No. 161 from *Blue M Electric Co.* illustrates line of electric ovens, furnaces, baths, environmental cabinets and related temperature-control equipment.

965. Tube Furnaces

Bulletin ZT-361 illustrates modernized line of zoned tube furnaces featuring interchangeable components for increased versatility. *Harper Electric Furnace Corp.*

966. Industrial Burners

The "Buzzer" line of burners needs no blowers, power or other auxiliary equipment to effect combustion; simply connect to the available gas supply. *Charles A. Hones, Inc.*

967. Quenching Oils

Four *Texaco* quenching oils assure the right cooling rate for any quenching application. Send for booklet, "Quenching and Hardening".

968. Optical Pyrometer

Catalog No. 95 covers "Pyro Micro-Optical" pyrometer which precisely measures targets as small as 0.001 in. diameter or remote objects. Temperature ranges, 1300 to 5800° F. *Pyrometer Instrument Co.*

969. Heat Treating Furnaces

"Automotion" furnaces operate automatically and continuously to assure uniformity of case and uniformity of hardening. *American Gas Furnace Co.*

970. Thermocouple Wells

Catalog G100-5 describes nine basic types of standard pressure-tight wells, with or without T/C assemblies. *Minneapolis-Honeywell.*

971. Thermocouple Alloys

Catalog manual from *Hoskins Mfg. Co.* contains detailed information on a complete family of time-tested Chromel-Alumel thermocouple-grade alloys developed especially to meet your application requirements.

972. Thermocouple Wire

Bulletin 1-500 gives the facts on "Xactpak" thermocouple wires with metal sheath and mineral insulation. *Claud S. Gordon Co.*

973. Batch-Type Furnace

Surface Combustion Div. will send information on the "Allcase" atmosphere furnace which automatically hardens parts and delivers them with uniform quality.

974. Heat Exchangers

Bulletins 120, 124 and 132 present the story on "Aero" heat exchangers for controlling the temperature of your quench bath. *Niagara Blower Co.*

975. Temperature-Indicating Paint

Folder from *Curtiss Wright* describes color-changing paints which indicate temperature and thermal distribution in a wide range of processing operations.

976. Radiant Tubes

The Pressed Steel Co. will send information on lightweight radiant tubes,

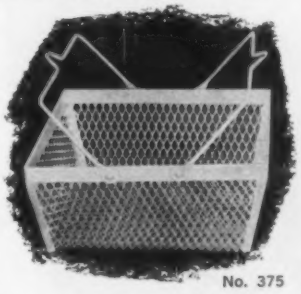
Circle appropriate number on Reply Card, p. 48-B

Show us the part!

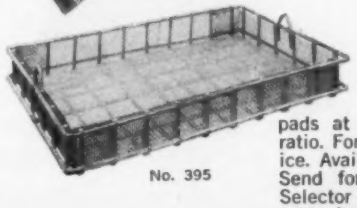
STANWOOD WILL BUILD A BETTER BASKET FOR THE JOB!

No. 377

Show us the part or a drawing of the part to be heat treated and tell us the quantity — Stanwood will recommend a basket design that will assure you of easiest handling in and out of furnaces and through quenching — a basket that will last longer and reduce costs in your heat treating department or shop. These Stanwood Baskets are cutting costs day after day.



No. 375



No. 395

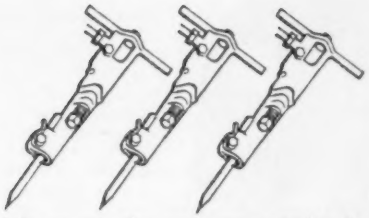
No. 377 is a drop bottom basket for carburizing bearing cases in a cyanide furnace — one of many designs of drop bottom baskets. No. 375 is a basket for degreasing and washing small parts. No. 395 is a lightweight furnace basket with built-in pusher pads at ends. Exceptional strength to weight ratio. For high temperature and quenching service. Available with replaceable wire mesh liner. Send for Stanwood Heat Treating Equipment Selector — Shows typical baskets, trays, fixtures, parts, boxes, retorts and furnace parts.

STANWOOD (HEAT TREATING S EQUIPMENT) **CORPORATION**

4817 W. Cortland Street — Chicago 39, Illinois

Circle 1095 on Page 48-B

The Porter Alloyist delivers the right alloy IN THE SPOTS THAT COUNT



There can be no compromise in metals for those tougher, tool-killing jobs. That's why the Porter Alloyist recommends Grade D phosphor bronze for the rifle nut in air hammers . . . the critical part of the tool that absorbs hundreds of vibrations a minute at high impact pressure. Produced at a special temper, this alloy has the required toughness and durability to do the job and to help keep tool maintenance costs low.

THE PORTER ALLOYIST IS A SPECIALIST IN A WIDE RANGE OF SPECIAL METALS

Porter's Riverside-Alloy Metal Division is your single reliable source for specialty alloys in 8 basic groups of wire, rod and strip . . . phosphor bronze, nickel silver, cupro nickel, brass, stainless steel, nickel, Monel and Inconel.

Ask for a free copy of "Alloys for Industry" describing our wide range of specialty alloys. Write H. K. Porter Company, Inc., Riverside-Alloy Metal Division, Riverside, N.J. Or contact our sales offices in Hartford, Chicago, East Orange, Atlanta, Cleveland, Detroit, Cincinnati, Los Angeles and Rochester.

PORTER nickel wire is used extensively in vacuum tubes and in other components for the electronics industry.

PORTER carbon steel wire reinforces hose for air hammers and other industrial equipment.

PORTER

RIVERSIDE-ALLOY METAL DIVISION
H. K. PORTER COMPANY, INC.
Circle 1096 on Page 48-B

available in any design, size range or alloy.

977. Thermal Systems

Minneapolis-Honeywell offers a pamphlet describing a gas-actuated thermal system for temperature recording; withstands extreme vibration and corrosion conditions.

980. Galvanized Steel

St. Joseph Lead Co. will send reprints of a report conducted by the Ford Motor Co. on various methods of combating corrosion in automobiles.

Finishing

981. Airless Spraying

Catalog from *DeVilbiss Co.* lists specifications on production pumps for single and multiple-gun operation and also includes data on auxiliary equipment.

982. Coated Abrasives

4-p. brochure from *Armour Alliance Industries* describes products and services of Armour's Coated Abrasives Div.

983. Spray Cleaner

"Diversey No. 519", a spray cleaner for ferrous and nonferrous alloys, is discussed in brochure available from *Diversey Corp.*

984. Addition Agent

Brochure 461 from *Frederick Gumm Chemical Co.* gives the facts on "Clepo Pickle Aid E-2", an addition agent for acid solutions which suspends any oil globules present and prevents redepositing on parts prior to plating.

985. Metal Finishing Guide

4-p. guide contains information on materials and compounds for finishing operations such as buffing, burring, polishing and satin finishing. *Lea Mfg. Co.*

986. Electroplating Equipment

4-p. leaflet describes 19 basic types of electroplating, polishing, and spray-painting equipment available from *J. Holland and Sons, Inc.*

987. Pressure Blasting

A report on pressure blasting published by *Norton Co.* discusses applications, media used, and proper selection of aluminum oxide and silicon carbide abrasives.

988. Electro Cleaner

Flyer No. M-205.1-60 introduces "Magnus 24-Y", an electrocleaning chemical designed for anodic (reverse current) and cathodic (direct current) cleaning of steel, iron, stainless steel, and copper prior to electroplating. *Magnus Chemical Co.*

989. Pickling Salts

Leaflet presents data on "Enth-Acid 97", an inexpensive nonfuming pickling solution for copper, brass, aluminum and other nonferrous metals. *Enthone, Inc.*

990. Plating Aluminum

6-p. Data Sheet No. 13 contains information on a new process for preparing aluminum alloys for electroplating with all commonly electroplated metals. *MacDermid, Inc.*

991. Ultrasonic Cleaning

Folder from *Acoustica Associates, Inc.* describes 20-kc. self-tuning, transistorized ultrasonic cleaning system for faster cleaning and lower production costs.

992. Chemical Milling

Eastman Kodak Co. has released booklet, "Etching, Chemical Milling and Plating With Metal-Etch Resist".

993. Metal Cleaning

Information on "Cerfa-Kleen" line of soak tank and power washer compounds — for cold and hot solutions. *E. F. Houghton & Co.*

994. Mutual Chromic Acid

80-p. booklet "Chromium Chemicals" includes discussion of mutual chromic acid (99.75% pure) for minimizing plating difficulties and expensive rejects. *Solvay Process Div.*

Welding

996. Welding and Brazing

56-p. catalog and instruction manual covers welding, brazing, soldering and fluxes. Properties, uses and application data included. *All-State Welding Alloys.*

997. Welding Guide

80-p. "Vest Pocket Guide to Better Welds" published by *Hobart Brothers Co.*, gives data on proper welding procedures and techniques, causes and cures of welding troubles, welding symbols, electrodes, definitions, joints, wires and fluxes, and power sources.

998. Plasma Spraying Process

Brochure 101 explains the plasma spraying process and applications in high-temperature protection, fabrication of parts of "unworkable materials" and deposition of carbide hardfacing. *Plasma Systems Corp.*

999. Stress Relieving of Welds

32-p. booklet answers many of the questions about why, when and what to preheat and stress relieve. Booklet EW-249 from *Hobart Brothers Co.*

1000. TIG Welding Guide

A new guide designed to assist welders in the proper use of tungsten electrodes has been published by *Sylvania Electric Products.*

1001. Automatic Welding

Sciaky Bros. Inc. has published a 28-p. booklet which describes new automatic fusion welding equipment and controls.

1002. Precision Brazing

Bulletin 5711A gives details on "Model LAC-200" conveyor brazing furnace. *C. I. Hayes, Inc.*

1003. Programed Stress Relieving

Folder DM-157 from *Hobart Brothers Co.* describes 400-cycle induction heating unit; simplifies preheating and stress relieving of arc welded joints.

1004. Gas Manifolds

12-p. catalog covers line of industrial gas manifolds, stationary and portable. *Linde Co.*

1005. Machine Welding

Air Reduction Sales Co. offers reprint entitled "Machine Welding of a Prepackaged Liquid Rocket Engine", by R. T. Hoetger and W. B. Moen.

1006. DC Arc Welder

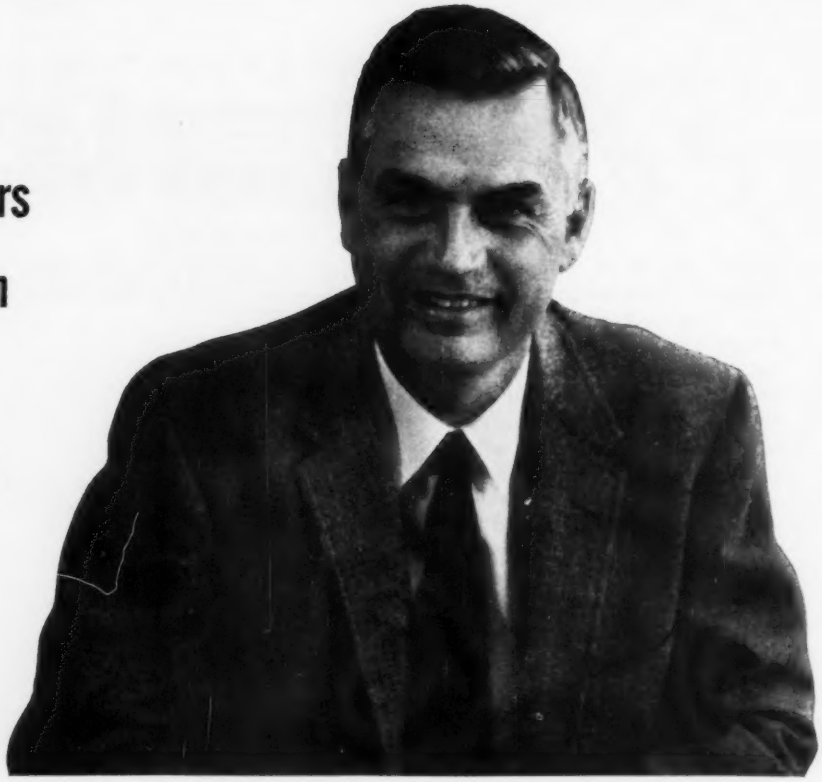
Pamphlet No. 4609.1 describes performance features and details of a line of three-phase rectifier d-c. arc welding machines manufactured by *Lincoln Electric.*

1007. Fine Powder Feeder

6-p. bulletin offered by *Sylvester & Co.* introduces "Sylco CCC" fine powder feeder designed for metering uniform quantities of powders, free from pulsations and interruptions.

Circle appropriate number on Reply Card, p. 48-B

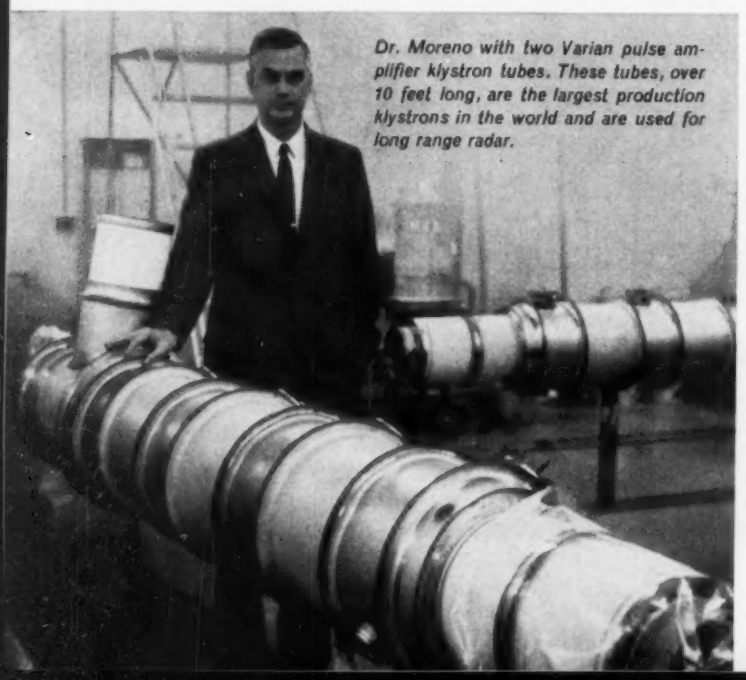
Lindberg atmosphere generators help VARIAN maintain rigid standards in volume production



Dr. Theodore Moreno, Vice President, Tube Division, Varian Associates, Palo Alto, California. Varian Associates is one of the country's foremost producers of equipment for a wide number of fields such as communications, navigation and aircraft control, advanced defense systems including early warning radars, and missile guidance, detection and ranging. Many Varian developments represent important advances in electronic technology.

QUOTE from Dr. Moreno

"Varian's success in the wide variety of electronic fields it serves depends not only on its ability to develop a technologically superior product but also on the development and maintenance of the production standards and capabilities required to retain this superiority in volume production. Our Lindberg Atmosphere Generators are making an efficient and dependable contribution to the consistent maintenance of these highly precise production standards."



Dr. Moreno with two Varian pulse amplifier klystron tubes. These tubes, over 10 feet long, are the largest production klystrons in the world and are used for long range radar.

Four Lindberg Atmosphere Generators are used at Varian Associates to provide dissociated ammonia atmospheres used in the production of microwave tubes. These include units with 1000 cfh, 2000 cfh, and 4000 cfh capacities. Varian also uses five Lindberg Furnaces for various research and production requirements. Lindberg has pioneered in practical equipment for producing all types of atmospheres for the treatment of metals and ceramics. If your product or processes need the application of atmospheres talk it over with Lindberg. Call your Lindberg Field Engineer (see your classified phone book) or write us direct. Gas Process Division, Lindberg Engineering Company, 2448 W. Hubbard St., Chicago 12, Ill.

Los Angeles plant: 11937 S. Regentview Avenue, Downey, California. In Canada: Birlefco-Lindberg Ltd., 15 Pelham Ave., Toronto 9, Ont. Also, Lindberg plants in Argentina, Australia, England, France, Italy, Japan, South Africa, Spain, Switzerland and West Germany.

Circle 1097 on Page 48-B

LINDBERG heat for industry

1008. Sprayed Overlays

Data Sheet No. T-3 discusses selection of metal powders for sprayed overlays. *Wall Colmonoy Corp.*

1009. Welding Equipment

Miller Electric Mfg. Co. has published literature on their "Model SR or SRH" gold star welders.

1010. Aluminum Brazing

Bulletin 23 supplies details on "Alumibraze 400", the homogeneous paste that is extruded onto parts with a gun; produces strong, sound, corrosion-resistant joints. *Handy & Harmon.*

1011. Automatic Welding

Hobart Brothers Co. has released brochure describing automatic welding equipment which can be used with inert gas, carbon dioxide — or as a submerged arc unit.

Testing

1013. Specimen Mounting Material

The *Fulton Metallurgical Products Corp.* has published a brochure describing "Quickmount", a fast-setting, self-curing specimen mounting material that produces clear mounts without application of heat or pressure.

1014. Hardness Testing

Illustrated reference book contains information on all hardness testing procedures. *Clark Instrument, Inc.*

1015. X-Ray Microscope

8-p. folder entitled "Isolation of Selected Elements With An X-Ray Projection Microscope" has been reprinted by *Phillips Electronic Instruments.*

1016. Spectrometric Equipment

Make 700 chemical analyses per shift with a "B-A" direct-reading spectrometer. Details from *Baird-Atomic, Inc.*

1017. Hardness Testers

Bulletin CRS60 from *Torsion Balance Co.* discusses "Kentrall" motorized hardness testers which remove major loads automatically, thus reducing operator error and increasing reproducibility of test results.

1018. Electromagnetic Tester

Budd Instruments Div. offers information on the "Metrol Heatcheck", which identifies alloys and heat treat conditions for both ferrous and nonferrous alloys.

1019. Universal Tester

Bulletin from *Wiedemann Machine Co.* gives the full story on the "Baldwin Mark B" universal testing machine.

1020. Portable Potentiometers

Leeds & Northrup will give you the full story on compact, portable potentiometers available in 15 temperature ranges.

1021. Atmosphere Analysis

MSA Instrument Div. has prepared bulletin on "Lira 300" furnace atmosphere analyzer for CO_2, CO, methane, and dew point.

1022. Magnaglo Inspection

For inspecting large complex-shaped castings, the "Magnaglo CRV-8" unit reduces inspection time up to 90%. Details from *Magnaflux Corp.*

1023. Horizontal Goniometer

As discussed in new bulletin, *RCA's* x-ray diffraction and spectroscopy equipment performs six functions, including crystal studies and spectroscopy of small areas.

1024. Electropolishing

The "Model 1720 AB" electropolisher is simple to operate and requires minimum maintenance. Brochure from *Buehler Ltd.*

1025. Metallurgical Microscopes

Microscope Catalog 2-S from *Unitron Instrument Co.* covers complete line of metallurgical miscroscopes and accessories for research, industry and educational applications.

1026. Testing Machine

The "Super L" is a testing machine designed to make wire testing easier and faster. Bulletin 47-W, *Tinius Olsen Testing Machine Co.*

1027. Neutrons From Small Tubes

Folder from *Phillips Electronic Instruments* gives design data on tubes which provide neutrons in quantities intermediate to those available from isotopic sources or reactors.

1028. X-Ray Equipment

Balteau Electric Corp. offers four technical papers covering use of portable x-ray equipment in aircraft maintenance and in storage tank fabrication, as well as radiography of fuel oil heater elements. Includes list of all nondestructive testing methods and applications suited to each.

1029. Strain Gages

Brochure lists 29 "Micro-Sensor" semiconductor strain gages . . . includes data on resistance, lengths, gage factors, curvature radii, temperature range, dimensions and price. *Micro Systems, Inc.*

1030. X-Ray Handbook

The Gevaert Co. of America has released 25-p. illustrated handbook covering industrial x-ray films and containing comparison tables.

1031. Gas Chromatography

2-p. Data Sheet E-ND46(9) describes "Speedomax G and H" recorders for laboratory gas chromatography applications. *Leeds & Northrup Co.*

1037. Spectrographs

The convertible "Ebert" spectrograph will do routine analyses and will also help solve tough "odd sample" or research problems. Information from *Jarrell-Ash.*

1038. Research Metallographs

Catalog E-240 describes line of research metallographs; widest range of illumination and magnification available. *Bausch & Lomb Inc.*

1039. Gamma Radiography

Budd Instruments Div. has released a pamphlet detailing the advantages of 21 standard "Iriditron" and "Multitron" gamma radiography instruments.

1040. Universal Testing Machines

36-p. Brochure No. 63 contains information on complete line of two-screw and four-screw universal testers. *Tinius Olsen Testing Machine Co.*

Casting

1042. High-Alloy Castings

Brochure G-159 from *Duraloy Co.* discusses the advantage of high-alloy castings used in metal treating operations.

1043. Induction Melting

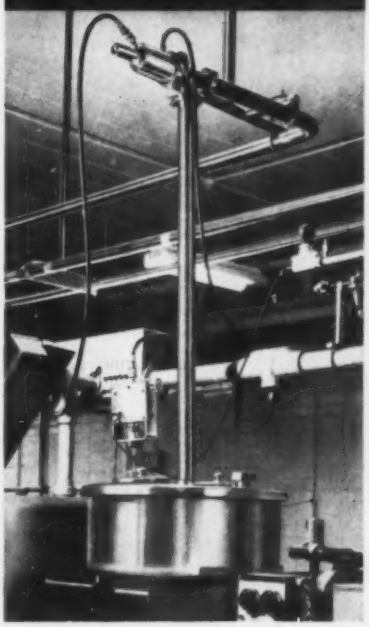
Bulletin 20-15 presents the facts on the "Inducto Integral 15", an M-G powered induction melting system from *Inductotherm Corp.*

1044. Block Insulation

Leaflet from *Johns-Manville* describes "J-M Superflex" block insulation which increases furnace efficiency and provides long operating life.

Circle appropriate number on Reply Card, p. 48-B

A-P-C
automatic
FLOW CONTROL



POSITIVELY... SHUTS OFF

POSITIVELY... THROTTLES

POSITIVELY... OPENS

Maintains constant liquid level in balance tank, filler bowl or wherever a uniform level is required.

Only with a combination like A-P-C's new Wizard level control and air operated automatic throttling valves can you be guaranteed of safe positive flow control. Protects against container over and under fills; avoids spillage and operates even under severe turbulence.

Look to Alloy Products Corp. for flow control components and systems.

Sold exclusively by the
Creamery Package MFG. CO. *for*

ALLOY PRODUCTS CORP.
Stainless Steel Craftsmen Since 1929
1053 PERKINS AVENUE
WAUKESHA, WISCONSIN

Circle 1098 on Page 48-B

INTERLOX...

a better, lower cost, easily controlled phosphate coating that LOCKS your finish to the metal.

Interlox's unusual cleaning ability and radically different type of accelerator produce an even, fine grained, dense coating that literally locks an organic finish to the metal.

Interlox gives you the ultimate in appearance, adhesion and corrosion resistance—no streaks, stains, powdery residue or flash rusting to complicate your production. Interlox baths are unusually long lived and require less replenishment and control.

Extra cleaning power is easily obtained at any time by the addition of a low-cost detergent only. This avoids the danger of over-phosphatizing by the costly practice of adding complete phosphatizing compound when only cleaner is needed.

There is an Interlox product to meet your particular requirements, whether spray or immersion type, single or multiple stage.

Licensed Manufacturers { **Alert Supply Co., Los Angeles, California**
Armalite Company, Ltd., Toronto, Canada

NORTHWEST CHEMICAL COMPANY
9310 ROSELAWN • DETROIT 4, MICHIGAN
CHEMICAL PRODUCTS DIVISION • CHEMETRON CORPORATION

Circle 1099 on Page 48-B

1055. Molding Machines

4-p. brochure from *Plastics Machinery Div.* discusses "Producto Versa-Blow" single and double press blow molding machine available in a wide range of speeds and capacities.

1056. Vacuum Induction Furnace

Bulletin 4-25 discusses vacuum induction furnaces which are available in capacities from 50 to 1000 lb. *Consolidated Vacuum Corp.*

1057. Control Motors

Heavy-duty electrical control motors provide more torque and more precise positioning for industrial valve and damper uses. *Minneapolis-Honeywell.*

1058. Oxygen Supplies

Air Reduction Sales Co. will give you the full story on oxygen supplies for metal processing operations.

1059. Vacuum Slide Calculator

F. J. Stokes Corp. will send free vacuum slide calculator as well as information on "Series H Microvac" pumps, the most advanced in their class.

1060. Conveyor Scale Systems

Information on conveyor scale systems and automatic weighing devices for instantaneous control of proportioning operations. *CompuDyne Corp.*

1061. Ferrochromium Alloys

Vanadium Corp. of America has released pamphlet on "Exlo 75", extra high in chromium and extra low in carbon (0.015% max. C and 75% min. Cr).

1062. Refining Fluxes

Leaflet A-9 published by *Foseco, Inc.* outlines properties of "Recupex" brand covering and refining fluxes for melting copper and nickel alloy scrap.

1063. Insulating Firebrick

4-p. brochure published by *Johns-Manville* describes two new firebricks with direct exposure and back-up insulation for atmosphere furnaces.

Parts

1065. High-Strength Fastenings

16-p. laboratory report from *Standard Pressed Steel Co.* analyzes high-strength bolt failures in aircraft and missile applications.

1066. Specialty Tubing

Literature from *Superior Tube Co.* describes specialty tubing for many applications including aircraft, missile, electrical, electronic, chemical, hydraulic, dairy and nuclear industries.

1067. Roll Forming

Bulletin 760 discusses high-speed roll forming techniques incorporating punching, notching, embossing and other secondary operations. *Roll Formed Products.*

1068. Bearing Terminology

24-p. booklet "Bearing Parts and Nomenclature of Standard and Precision Bearings" defines and illustrates bearing parts and terms. *SKF Industries, Inc.*

1069. Metal-Mesh Belts

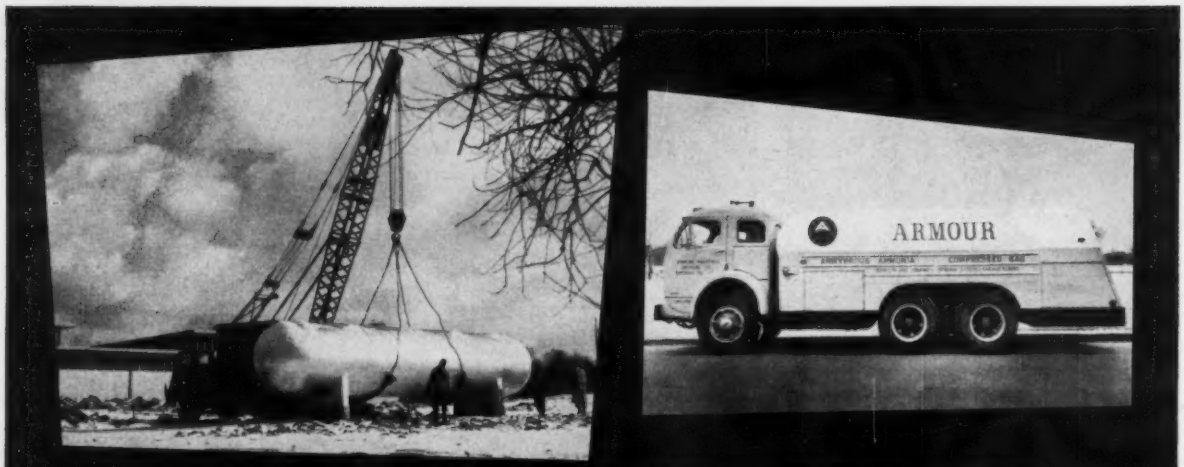
130-p. reference manual from *Cambridge Wire Cloth Co.* discusses metal-mesh belts including "Cambriloy 35-19" belts for aluminum and copper brazing operations.

1070. Stainless Screws

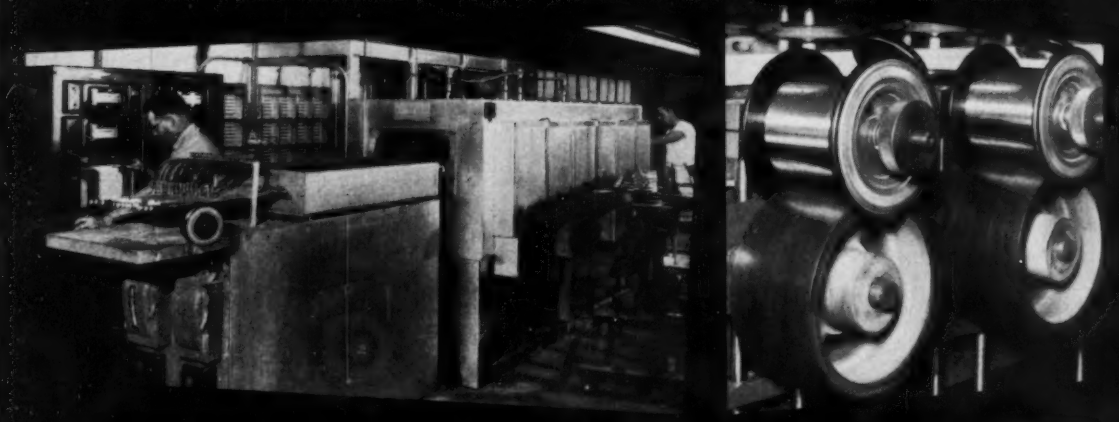
4-p. leaflet from *Standard Pressed Steel Co.* gives specifications and performance data for "Unbrako KS 812" (125,000 psi.) stainless steel socket-head capscrews.

CHAMBERSBURG
NOW!
AUTOMATIC FORGING IN
JOBBING LOT QUANTITIES
Made possible by the
MODEL "C" IMPACTER
with
a unique program-controlled Feed Device
A "BREAKTHROUGH" IN THE MECHANIZATION
OF THE DROP FORGING PROCESS
Write for new bulletin No. 110-L-1 "Chambersburg Cecomatic Process for the Jobbing-Type Production of Drop Forgings"
CHAMBERSBURG ENGINEERING COMPANY
CHAMBERSBURG, PA.

Circle 1100 on Page 48-B



AT FORT WAYNE METALS, ARMOUR AMMONIA HELPS



CUT COSTS OF BRIGHT ANNEALING STAINLESS STEEL WIRE

Why ammonia? "We found that dissociated ammonia, derived from anhydrous ammonia, costs us $8.00 per hour less to use than bottled hydrogen," says Ardelle Glaze, president of Fort Wayne Metals, Inc. "This saving is based on all costs—raw material, labor, storage space. And we get the same results from dissociated ammonia with dew points ranging downward from −55° F."

How much can you save? Based on average prices of both anhydrous ammonia and hydrogen, each 1,000 cu. ft. of dissociated ammonia atmosphere saves about $10.00. Exact savings depend on local conditions and quantities used.

Why Armour? Says Mr. Glaze: "Our critical specifications demand high-purity ammonia, and we've always been well satisfied with the results from Armour ammonia. Armour technicians helped engineer our first ammonia installation and have assisted us when needed over a 15-year period. What's more, they helped us install a new 10,000-gallon ammonia storage tank."

Call Armour for your ammonia needs—always tested to be at least 99.98% *pure on delivery*. Fast delivery—171 distribution points across the country. Backed by technical service, at no cost. Let your Armour ammonia representative help determine your potential savings.

AMMONIA SALES

Armour Industrial Chemical Company

One of The Armour Chemical Industries

110 North Wacker Drive • Chicago 6, Illinois

Circle 1101 on Page 49-B

The ASM is the communications center for technical information wherever metals are produced, processed, fabricated, designed, tested and applied. Metal Progress, monthly engineering magazine of the Society, reports on engineering developments in these 11 major technological areas:

FERROUS METALS

NONFERROUS METALS

HEAT- AND CORROSION-RESISTANT AND ELECTRICAL MATERIALS

RADIATION AND NUCLEAR MATERIALS & EQUIPMENT

TOOL MATERIALS, CUTTING AND FORMING EQUIPMENT

INDUSTRIAL HEATING EQUIPMENT AND SUPPLIES

CLEANING AND FINISHING EQUIPMENT AND SUPPLIES

WELDING AND JOINING EQUIPMENT AND SUPPLIES

INSPECTION AND CONTROL EQUIPMENT AND SUPPLIES

PRODUCTION AND CASTING EQUIPMENT AND SUPPLIES

PARTS, FORMS AND SHAPES FOR DESIGN AND APPLICATIONS

FIRST CLASS
PERMIT NO. 146
ST. JOSEPH,
MICH.

BUSINESS REPLY CARD
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METAL PROGRESS
215 WAYNE STREET
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READER SERVICE DEPARTMENT

September, 1961 Issue
METAL PROGRESS

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READER SERVICE DEPARTMENT

September, 1961 Issue
METAL PROGRESS

Complete Reader Service Information With These Convenient Prepaid Cards

Catalogs and bulletins, new products and services and most advertisements in Metal Progress are numbered. To receive more information, circle the appropriate numbers on one of these postage paid cards. Editorial reprints will be sent free as long as they last.

Catalogs and Bulletins are available from a *scrutinized* and up-to-date list of manufacturers' literature, conveniently indexed under the 11 major Engineering Areas.

More Facts on Advertised Products. Because some advertisements cannot be numbered, please write the names of those advertisers in the blanks provided.

New Products and Services are numbered. Circle the postcard for more information.

Reprints of Articles are yours for the asking as long as they last. No need to clip your Metal Progress issue for reference filing; send for reprints.

Please Include Your Name and Address!

Metal Progress September, 1961 Issue

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Metal Progress September, 1961 Issue

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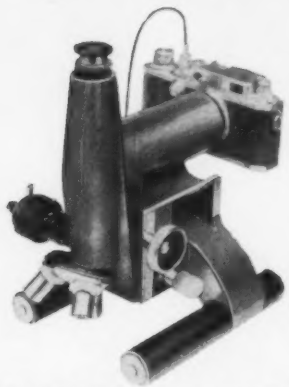
If METALLURGY is your field, UNITRON is your microscope

Binocular Inverted Model BMEC with camera mechanism.....$615.
Monocular Inverted Model MEC.....$399.
(Polaroid Land Camera attachment available)

Model MMA.....$149. Model MMU.....$287.

Binocular Metallograph BU-11.....$1379.
Monocular Metallograph U-11.....$1195.
Polaroid Land Camera attachment.....$115.

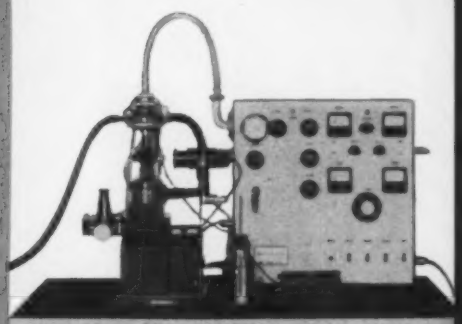


Model DMR Depth-Measuring Rollscope for examination of large or cylindrical surfaces.....$445.

Projection Screen..$95.

Toolmakers and Metallurgical Microscope Model TM for 3-dimensional measuring.....$1030.
(other models available)

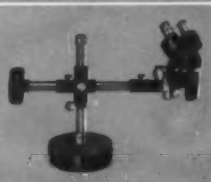
UNITRON'S Complete Laboratory Installation for High-Temperature Metallography with Metallograph and HVC-3 Control and Power Station.



Stereoscopic Model MSL.....$110.

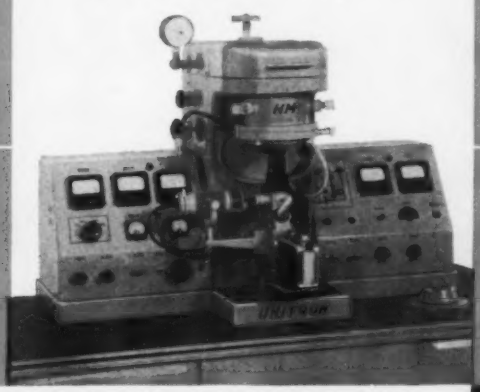
Stereoscopic Model MSM with turret changer.....$320.

Stereoscopic Model MSHL with revolving nosepiece.....$267.



Pillar Stand for Stereoscopic Models.....$75.

UNITRON'S Research Installation for High-Temperature Microscopy, Desk Model HM
(Write for price and complete specifications)



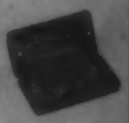
HHS-3 Vacuum Heating Stage for 1500° C.....$625.

Long Working Distance Objective FF40X.....$149.

Goniometer Eyepiece from $55.

Anatomic Grain Size Eyepieces:
Turret-Type..$76.
Ke 10X.....$25.

Filar Micrometer Eyepiece..$69.50



Stage Micrometer $11.

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to meet every metallurgical application . . . from low-power macro to high-power micro examinations, right on through to advanced research in high temperature studies of the new metals in the space age. And when it's time to balance your equipment budget against your needs, UNITRON prices will be among the best news of all.

TRY A UNITRON IN YOUR LAB . . . FREE, FOR 10 DAYS

A salesman's demonstration gives you only about 30 minutes to examine a microscope . . . hardly the best conditions for a critical appraisal. But, UNITRON'S Free 10-Day Trial allows you to use the microscope in your own lab and put it through its paces on your own particular problem. Use the coupon to ask for a no-obligation, prepaid trial. And if you want more details on these and other UNITRON Microscopes, use the coupon to request a complete catalog.

Circle 1102 on Page 48-B

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Steel

PHOTOGRAPH BY PAUL WELLER

THE FINER TOUCH

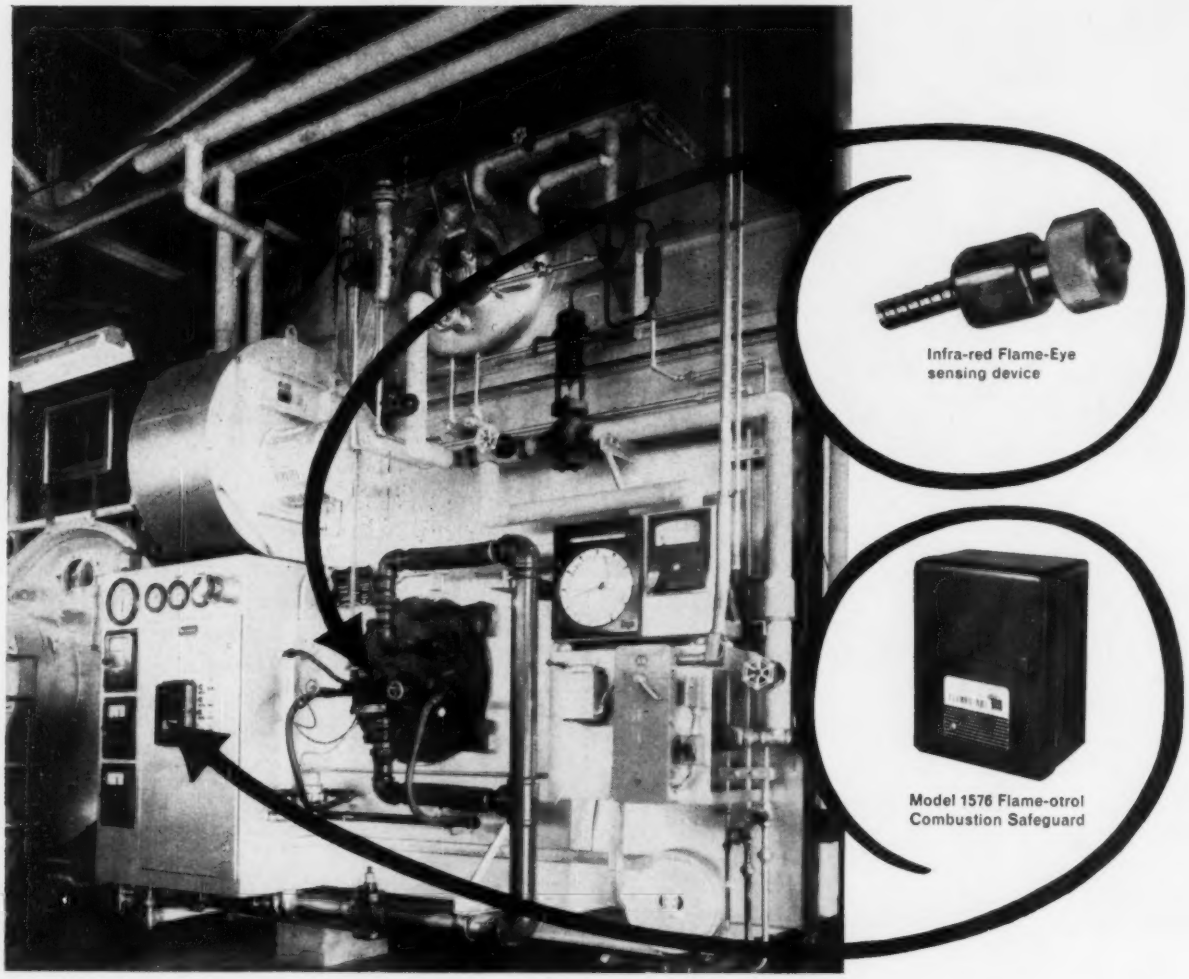
Accuracy. By a steelmaking specialist. Ladle a sample. Test. Check again and again ■ Much may depend on tiny pellets of alloying metal in a furnace of molten steel. The strength of a bridge or a fractionating tower. The corrosion resistance of a processing vessel. Accuracy is essential to the skilled builders of these vital projects. ■ And accuracy is a characteristic long associated with Lukens—in producing the highest-quality carbon and special-duty plate steels and head shapes. In researching the best steels for difficult applications. The Lukens Application Research team would welcome the opportunity to work with your engineers on problems that involve designing with plate steels. Please write, or call collect, Manager of Application Engineering, 44-B Services Building, Lukens Steel Company, Coatesville, Pennsylvania.

THE SPECIALIST
IN PLATE STEELS

LUKENS STEEL

COATESVILLE, PA.

Circle 1103 on Page 48-B



Barber-Colman Model 1576 Flame-otrol and Flame-Eye protect steam generator used for process and space heat.

Fool-Proof Combustion Safeguards Eliminate False-Alarm Shutdowns

Now, there's no need to let nuisance burner shutdowns interrupt process heat and waste costly production time. Barber-Colman Flame-otrol Combustion Safeguards are fool-proof! Flame-otrol Systems ignore false signals from flame flicker, bright backgrounds, colorless flames or refractory radiation to maintain production.

Complete line of infra-red and conductivity-rectification safeguard systems give you automatic safe starts: programmed purging, warm-up proving, pilot proving, ignition and sequence timing. Barber-Colman Flame-otrols monitor flames with manual, semi-automatic or automatic operation. They protect combination gas, oil or powdered-fuel furnaces, boilers, kilns and dryers.

Flame-otrols feature easy-servicing plug-in chassis, convenient external check points and standard electronic tubes. For maximum control flexibility, Flame-otrols can be interlocked with any instrument control system. Contact your nearby Barber-Colman Sales and Service Engineer today. He's in the Yellow Pages.

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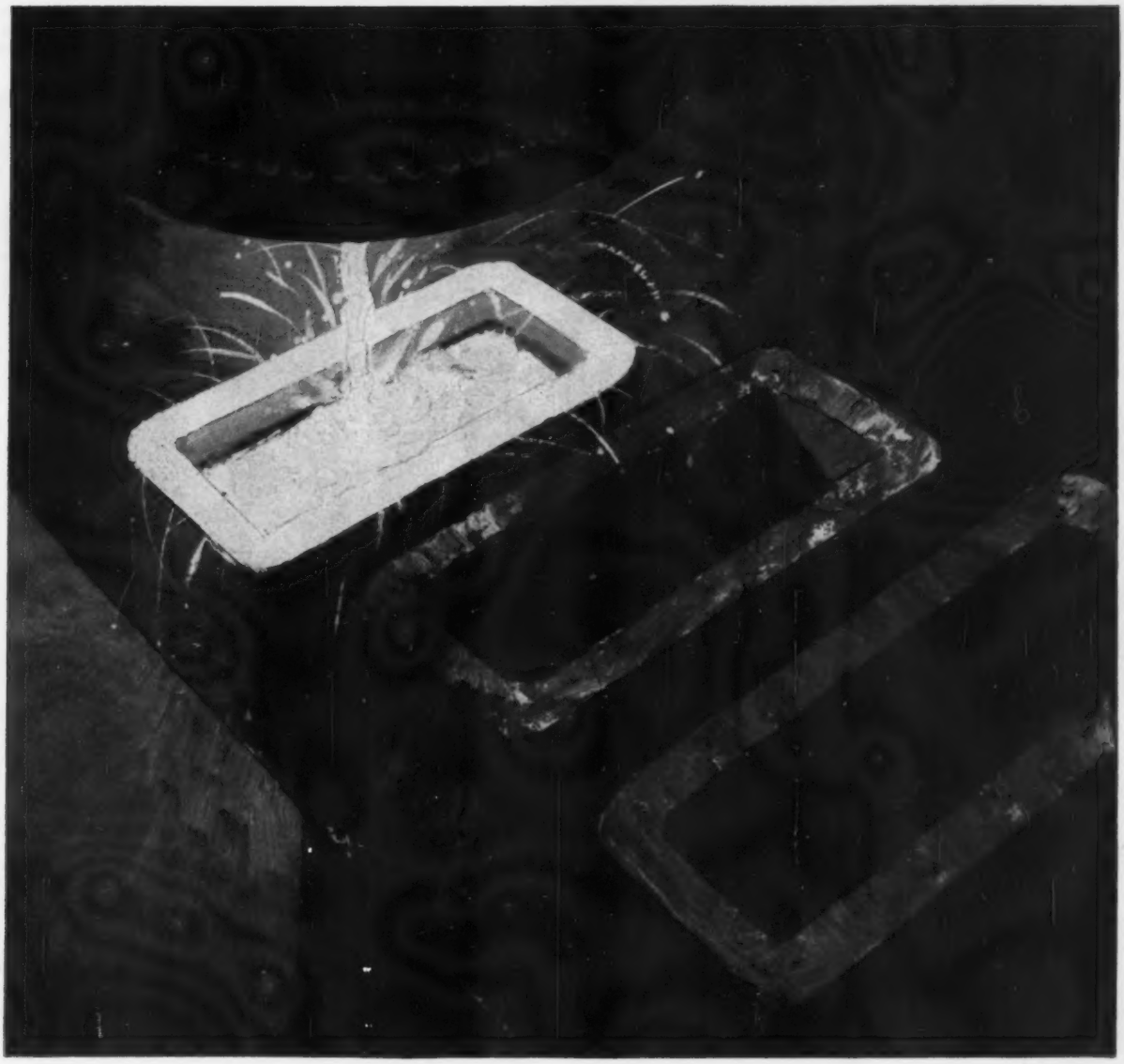
Circle 1104 on Page 48-B



Rimming steel in 70,000 lb. ingots with MCA FLUX

Keeping ingot sizes small in rimming steel has been associated with quality and handling facilities.

Now by the use of MCA Flux you can make large rimming ingots and maintain the deep drawing quality of smaller ingots. Faster rimming, scattered and smaller inclusions, reduced sulphur, uniform chemistry and better surface are obtainable by MCA Flux treatment.

It is no longer necessary to produce small ingots which make only slab and half cuts. Take advantage of larger ingots and obtain savings by less handling, more pit space, good surface. MCA Flux can assure you of all of these and maintain high quality standards for deep drawing rimming steel.

Write to us for complete information.

MOLYBDENUM

CORPORATION OF AMERICA

1312, Building Number 4, Gateway Center, Pittsburgh 22, Pa.

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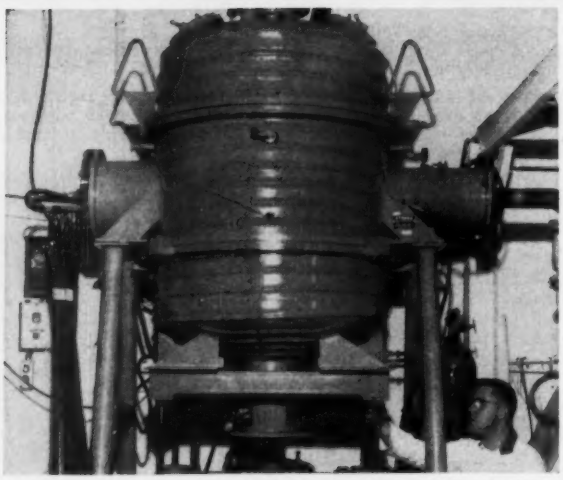
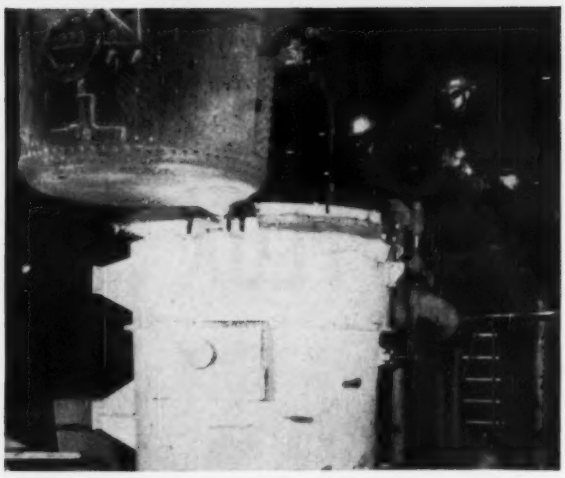
Sales Representatives: Brumley-Donaldson Co., Los Angeles, San Francisco
Subsidiary: Cleveland-Tungsten, Inc., Cleveland
Plants: Washington, Pa., York, Pa.

Circle 1105 on Page 48-S

One of the largest cold-wall vacuum heat treating furnaces ever built, capable of operations at temperatures above 2000°F. was recently installed by Stokes. The huge furnace will be used in brazing and heat treating the high alloy steels used in the production of missile components. It has a vacuum chamber 12 feet long and 9 feet in diameter.



Uranium melting on a production basis is accomplished by this Stokes induction melting furnace at Atomics International. Designed for safety and convenience, the furnace is serviced from the top and features a removable bottom section to facilitate handling of cast materials.



First acid open hearth, vacuum stream ladle degassed, air-pouring of multiple ingots in the U. S. took place at Ohio Steel Foundry in Stokes equipment. Results showed low hydrogen values, good inclusion reduction and excellent physical property improvement.

CUSTOM APPROACH TO YOUR UNACCUSTOMED PROBLEMS...

a Stokes specialty in vacuum metallurgy

Staffed and equipped to undertake projects which contain unusual problems, Stokes offers the most comprehensive background of vacuum metallurgical experience and know-how available today. Stokes is geared to tackle even the most complex assignments . . . assignments for which the application of high vacuum is the only practical solution.

New vacuum methods and techniques—first introduced by Stokes—are helping to capitalize on more and more opportunities in the metallurgical field. These advances are helping industry break through old bottlenecks . . . while reducing operating costs. In the nuclear field, for example, Stokes equipment has been used to develop new methods for plutonium melting and casting, uranium melting on a production basis, and radioactive materials handling. In metal refining, hydrogen embrittlement is being reduced with the aid of Stokes vacuum stream degassing equipment. In melting, heat treating, sintering and brazing . . . and in vacuum metallizing of thin and heavy coatings for decorative and functional applications . . . Stokes leads the field in new developments.

Advantages that take the guesswork out of operations . . . and brighten profit potential are inherent in Stokes equipment. For instance, we have demonstrated our capability in supplying a complete turnkey installation—erected, tested and delivered in operation. And our stocked components mean faster delivery, fewer costly holdups. All Stokes systems are offered complete . . . Stokes is your single source of responsibility for performance and reliability both before and after the sale.

Let Stokes put its unique experience and facilities to work on your problems. Our Engineering Advisory Service will help you in planning and designing an installation that will best serve your exact requirements. And whatever those needs are, the inherent flexibility of Stokes design concepts is assurance that they will be satisfied.

STOKES

Vacuum Metallurgical Division

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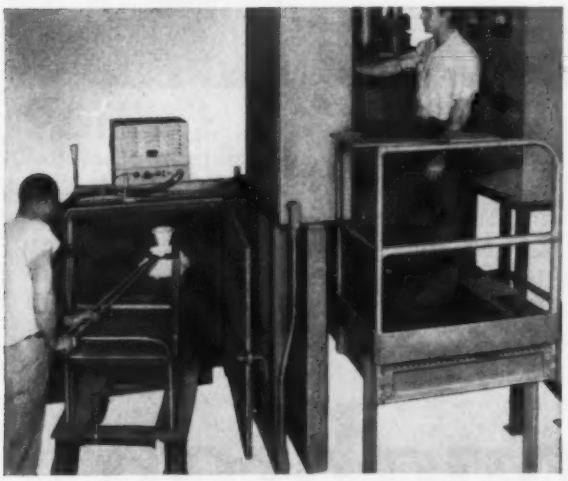


At Misco Precision Casting Co., semi-continuous vacuum melting and casting are being accomplished in two Stokes induction furnaces. Successive charges of the metal are introduced into the vacuum chamber from the outside, loaded into the crucible, melted, poured, and the cast pieces (in their molds) removed from the chamber . . . without breaking the vacuum.

Vacuum equipment capable of brazing panels in excess of 50 sq. ft. is being used in pilot operation by Grumman Aircraft Engineering Corporation to fabricate structures for the "Eagle" air-to-air missile. The Stokes equipment employs a new procedure which eliminates expensive and time-consuming welded "envelopes" to enclose the work. And high vacuum eliminates the need for costly inert gas.

Circle 1106 on Page 48-B

HOUGHTON MACHINING COOLANTS

A new advance in synthetic coolants

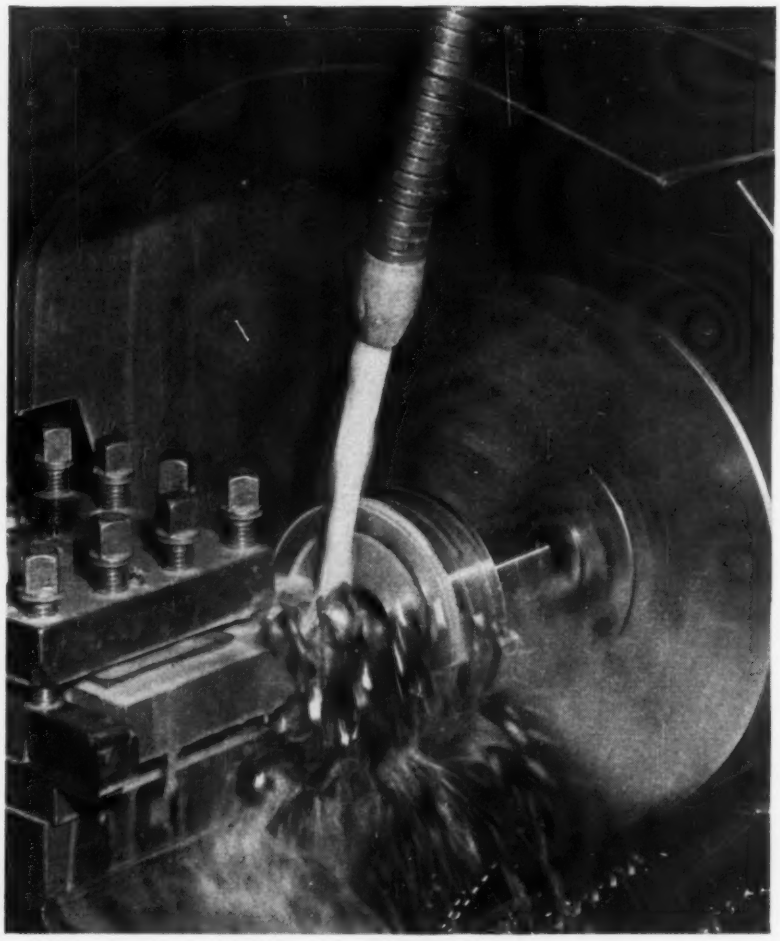
The first chemical coolants were outstanding in controlling rust and rancidity. They have done a good job and are widely accepted for many metal removal operations.

Because they were not heavy-duty fluids, our research department continued its search for a chemically-conceived coolant that could take the place of highly fortified straight oils. The result is new Hocut 3210—a significant advancement in the science of machining coolants.

Hocut 3210 is a highly fortified water-soluble concentrate. It has outstanding anti-weld and extreme pressure characteristics. As a result, it does better those jobs previously reserved for fortified straight oils. Hocut 3210 improves finish at higher speeds without sacrificing tool life. Additionally, it eliminates smoke, oil fog and inherent fire hazards.

Hocut 3210's E.P. characteristics are released by the heat of the cutting operation. This forms a barrier between the tool and the work resulting in a clean cut, free from any welding of chip to tool. Tool life is increased, surface finish improved and parts come off the machine cool enough to handle.

Its heavy duty ability makes it an ideal coolant for tough jobs such as tapping, broaching, form grinding, internal and external thread cutting, thread rolling, plunge grinding, etc.



In spite of all the outstanding features and capabilities of Hocut 3210, its cost is most reasonable. To be up to date on this latest coolant advance, write for complete data or ask your nearby Houghton Man for a test in one of your tough jobs. E. F. Houghton & Co., 303 W. Lehigh Ave., Philadelphia 33, Pa.

Houghton

INDUSTRY'S PARTNER IN PRODUCTION

Circle 1107 on Page 48-B

This is the first in a Series of Comments on various and vital aspects of Service in the Ferroalloys Industry.

at Vanadium Corporation of America

SERVICE COMES FIRST

Over 55 years ago when we began business as one of the first U.S. producers of ferroalloys, the factors of Price, Quality and Service were, even as they are today, the governing features of any progressive business organization. But time has proven that their interrelationship has changed; Service has now taken on new importance.

Service is Vital The first two—Price and Quality—are actually basic. It is obvious that the producer must charge a competitive price or his goods pile up on the shelves—unsold. He must also offer quality merchandise or his customers soon go elsewhere. Service, on the other hand, varies widely from producer to producer, and it is in this area that the buyer stands most to gain.

Service, however, cannot stand alone without the supporting influence of a fair return for the product sold, which not only makes available a quality product but also allows the producer to explore for new low-cost sources of raw materials, to maintain modern efficient production equipment, supply technical service and carry on the all-important Research and Development activities.

Few Offer All Three We believe that any producer in our industry today who does not provide for all three—Price, Quality and Service—is failing in his responsibility to his customers. Nearly all producers offer competitive price—somewhat fewer furnish top quality—but the great majority, including suppliers of foreign-produced material, are not prepared to extend more than minimum service.

Vanadium Corporation, on the other hand, offers you complete service. Here's what we mean:

Our Own Mines—Integrated mining and milling facilities provide, on a long-term basis, a consistent supply of high grade ores of controlled quality. Producers who rely on the purchase of distressed lots in the world market may temporarily profit but jeopardize the customers' requirements for a dependable and continuing supply of quality products.

Modern Plant Facilities—Our plants are among the most modern in the industry and are strategically located near consuming industries.

Production Planning—An extensive production-planning group assures you of an adequate supply of quality products—when you need them! Expeditious handling of every order is facilitated by a private network of teletype equipment linking district offices, plants, Research Center and headquarters offices.

Research Center—We are among the few ferroalloy producers who can claim the distinct advantages of fully equipped modern research facilities. This R and D supervision, over short-and long-term work, assures the development of new and better products, and provides adequate technical customer service.

Pilot Plant—Here complete facilities prove a product under actual operating conditions before it is ever offered commercially. The plant also provides complete customer service.

Engineering Sales—Widely experienced technical field personnel are located in district offices near you, always on call.

Field Stocks—Adequate stocks of required products are available in mill quantities when you need them.

Distribution—Vancoram Products are available from distributors with warehouses conveniently located throughout the country.

Over 4,000 VCA employees staff these facilities with a devoted interest in you—the customer.
When you think of ferroalloys—think of Vancoram, where SERVICE COMES FIRST.

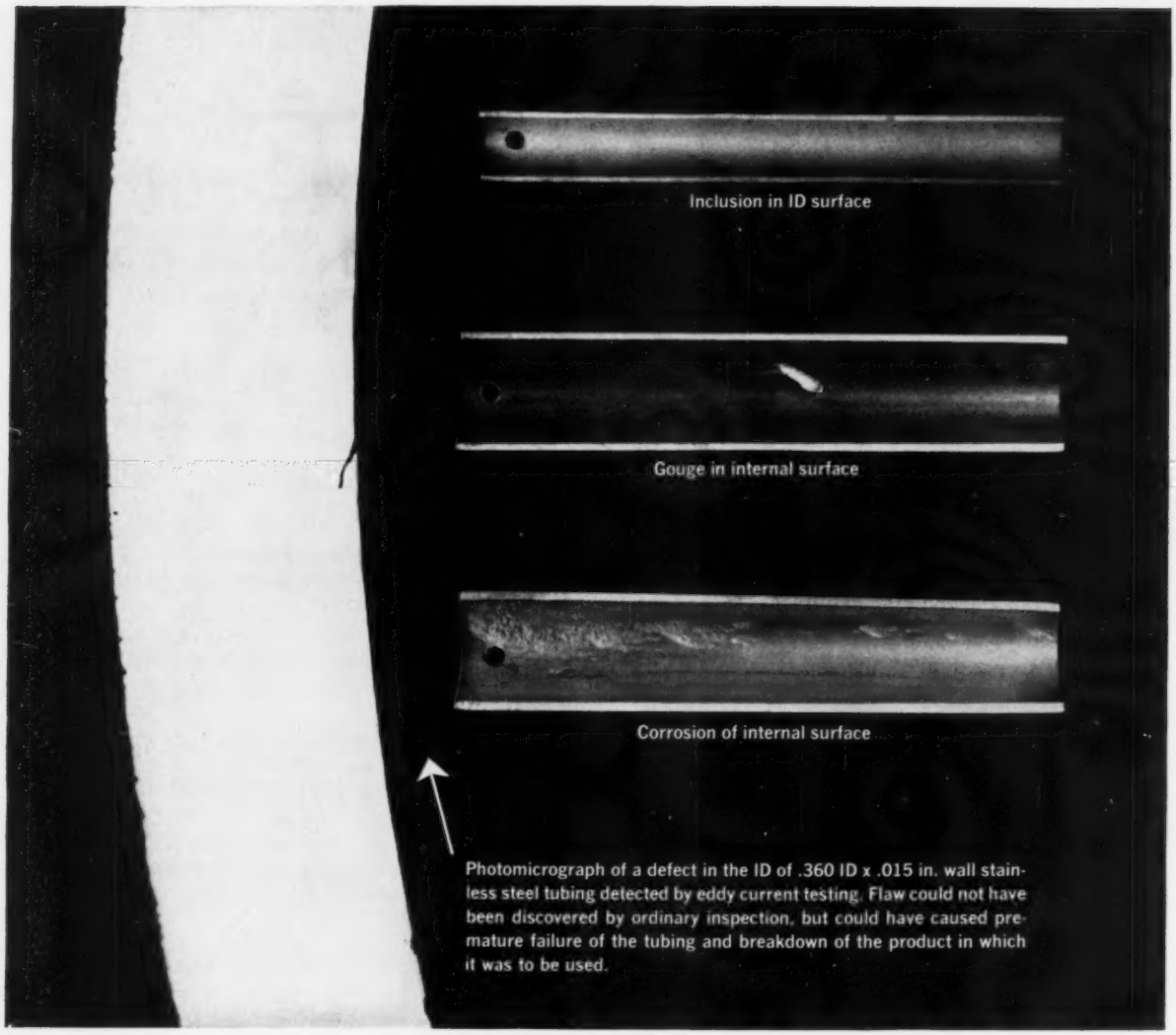
SERVICE COMES FIRST

VANADIUM CORPORATION OF AMERICA

420 Lexington Ave., New York 17, N.Y. · Chicago · Cleveland · Detroit · Pittsburgh

Circle 1108 on Page 48-B

Tomorrow's tubing technology — today



Photomicrograph of a defect in the ID of .360 ID x .015 in. wall stainless steel tubing detected by eddy current testing. Flaw could not have been discovered by ordinary inspection, but could have caused premature failure of the tubing and breakdown of the product in which it was to be used.

Tubing Quality Verified by Nondestructive Tests

Superior tubing for critical applications must be consistently of highest quality and reliability. As a consequence, nondestructive testing is essential. Furthermore, several types of test should be performed, since no one test is versatile enough to supply all the required information.

Eddy current spots defects we don't want in Superior tubing, but it doesn't tell us everything about them. Neither does any one of the other seven nondestructive tests we use in checking the finished quality of our tubing.

Depending on how critical the end use of the tubing is and thus the amount of test information required, we can perform any of the following tests singly or in combination: eddy current, dye penetrant and fluorescent dye penetrant, ultrasonic, radiographic, hydrostatic, boroscopic and magnetic particle. Only in this way can we detect imperfections such as change in analysis and dimension, pits, roughness, inclusions, weld defects, carburization, porosity, corrosion, laps, embedded particles, and surface oxides on OD and ID and in the wall of the tubing.

An article, "Nondestructive Testing of Small Tubing," details and compares the methods used. If you would like a copy, and technical data on the more than 120 analyses of small-diameter tubing produced in our mill, write us. Superior Tube Company, 2008 Germantown Ave., Norristown, Pa.

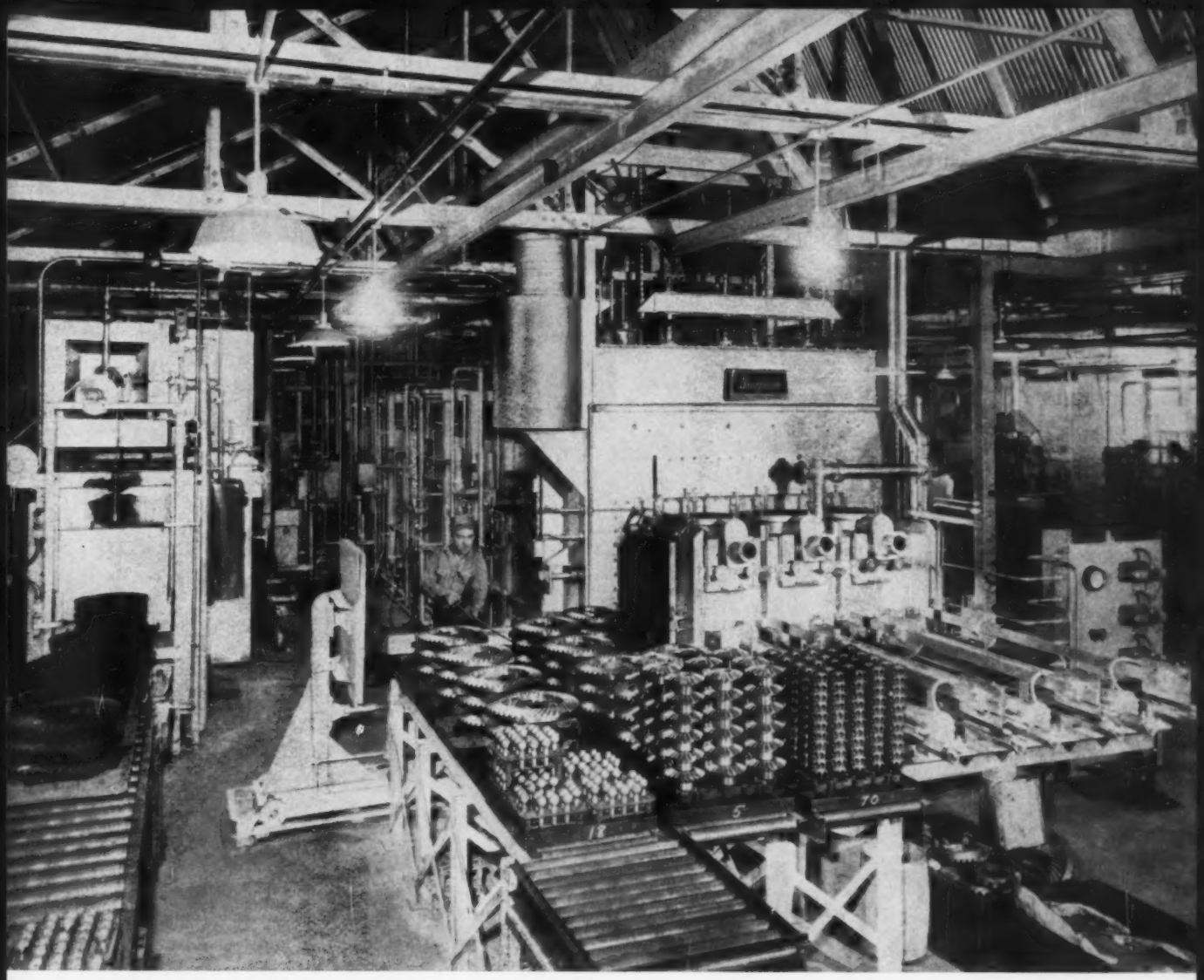
Superior Tube ST

The big name in small tubing

NORRISTOWN, PA.

West Coast: Pacific Tube Company, Los Angeles, California

Circle 1109 on Page 48-B



Continuous carburizing furnace replaces pack processing at a profit.

Several pack carburizing furnaces have been replaced by one Surface continuous gas carburizing furnace which has paid off for the White Motor Company.

They have improved the quality and uniformity of finished parts as a result of superior process control. At the same time, they are cutting inspection costs and realizing more efficient floor space utilization. Costly supply inventories required by former processes have been eliminated.

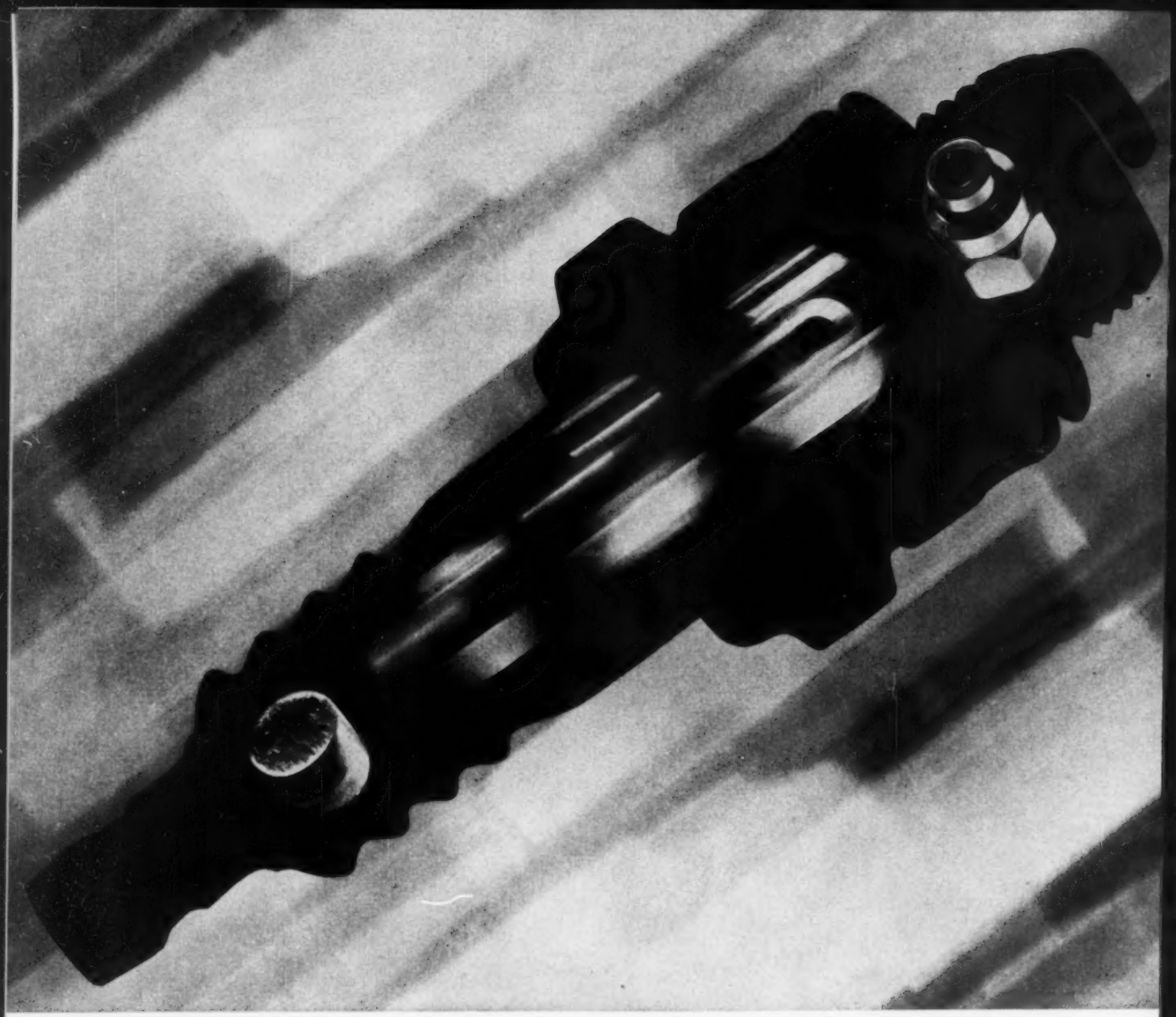
Atmosphere carbon potential in two of the five furnace zones is monitored automatically by a Surface Autocarb® System. Parts requiring press quenching are removed through a special slot door at right angles to the regular discharge door. The 57′ furnace carburizes 700 pounds/hour of ring gears, spider gears, studs, pins, and heavy parts.

Write for information: 2377 Dorr St., Toledo 1, Ohio. In Canada: 2490 Bloor St., West, Toronto.

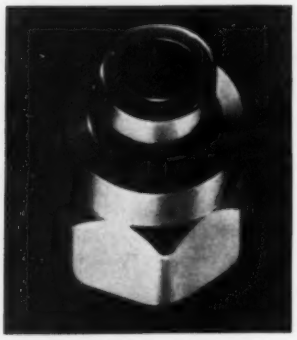
SURFACE

SURFACE COMBUSTION, Toledo 1, Ohio/ a division of Midland-Ross Corporation

Circle 1110 on Page 48-B



Spark Plug Shells: 86% Faster



STRONG
MODERN
DEPENDABLE

In a mere five-second sequence, machining requirements are trimmed 95%. Material waste is practically eliminated. Spark plug shells are *extruded* from cold steel.

New on the American scene, this is precision cold extrusion. The rewards are great but the technology can be complex. Read the special report dealing with cold extrusion on the opposite page.

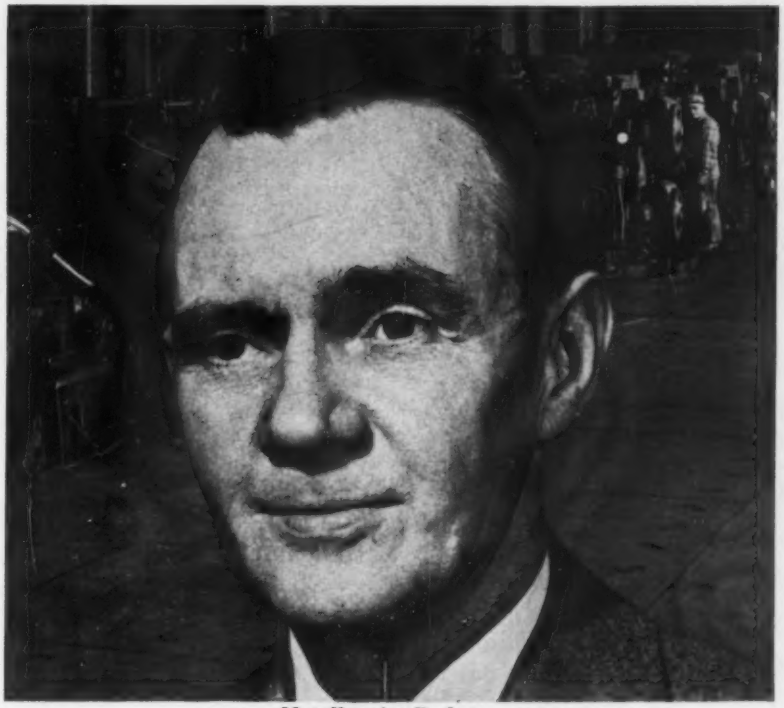
Republic Steel is the nation's largest supplier of carbon and alloy steels for precision cold extrusion—hot rolled, cold finished, and wire. More cold extrusion experience promises to save you time and money.

May we serve you? For complete information, contact your nearest Republic sales office or write: *Republic Steel Corporation, Dept. MP-2210-A, 1441 Republic Building, Cleveland 1, Ohio.*

REPUBLIC HAS THE FEEL FOR MODERN STEEL

Trial, Error, and 30% Savings

Precision cold extrusion is slashing steel waste, producing steel parts faster, but you need more than steel



Metallurgist Rodgers

Chief Metallurgist Bill Rodgers (right), Republic Steel Corporation, helps people produce three steel parts for the price of two. It's being done, by a growing number of Republic customers, and a process called cold extrusion.

With one of the largest field metallurgical staffs in the industry, Rodgers and Republic are helping customers make the cold extrusion process work. It isn't easy. You need a feasible part design, adequate production run, the right steel, extrusion dies that can deform cold steel without destroying it, and proper lubrication to assure uniform movement. Despite progress, trial-and-error is the rule rather than the exception in determining final die designs and material specifications.

Impact of cold extrusion—"Whether or not the public hears of cold extrusion, they're going to feel it," says Rodgers. "Here is a process that can cut the cost of steel parts by 30-50%. It's especially suited to big production runs—parts produced in the tens or hundreds of thousands. Potential savings are fantastic."

The nation's largest supplier of steels for precision cold extrusion, Republic is involved in two out of every four parts produced by this new method. This experience is utilized to its full advantage by customers. As for steel, Republic has built new facilities (the $20 million Chicago 11" bar mill, for example), and modernized existing facilities such as the Canton 8" mill, to supply the products needed.

The process—According to Rodgers, extrusion dies are designed to confine and direct the deformation of steel under severe pressure. Completed or nearly completed parts are produced in one operation. Machining requirements are always reduced, often eliminated.

Five great economies—

. . . Faster production. Steel can be extruded or deformed faster than it can be cut or milled.

. . . Less handling. Steel for cold extrusion normally enters production equipment in the form of coils and bars, leaves as a finished or nearly finished part.

. . . Less material waste. One spark plug shell manufacturer has reduced steel waste by 95%.

. . . Less machining. The cold extrusion process reduces or eliminates machining. Tolerances and surfaces are excellent.

. . . Stronger parts. Cold extrusion assures more uniform flow lines of the grains. As the process is a form of cold work, physical properties of the steel are increased.

What kind of steel—"Primary requirement is that steel be properly conditioned and in suitable tempers," says Rodgers. "Chemistries depend on the physical requirements of the completed part and on the capabilities of the cold extrusion equipment. We work with the customer and his equipment supplier in determining the best steel, proper thermal treatment, and design considerations."

According to Rodgers, proper annealing is especially important in cold extrusion. Annealing increases the malleability, uniformity, and internal quality of steel. Because of this, Republic has installed new atmosphere controlled, continuous annealing furnaces in the Chicago 11" bar mill. Hot rolled, cold finished, or wire drawn steels are supplied in coils, cut lengths, and occasionally in blanks."

Role of tool and design engineers—

—Parts are normally redesigned to suit or simplify the cold extrusion process. It is the tool and die engineers or the design engineers, according to Rodgers, who most often spot the potential application. With the help of equipment manufacturers and the steel supplier, these men determine precise section changes, required extrusions, and suitable steel chemistries. It remains for the tool and die engineer to design and produce the most important ingredient of all—the cold extrusion dies.

More than steel—"We can supply steel for cold extrusion from any of our bar mills, and from our Union Drawn or wire mills," says Rodgers. "More than that, we offer the technical assistance. Republic is supplying steel used in the cold extrusion of spark plug shells, piston pins, gears, shafts, universal yokes, valve lifters and caps, pivot nuts, missile components, military gun barrels, and many other parts. We do our best to save the customer time and money."

REPUBLIC STEEL

GENERAL OFFICES • CLEVELAND 1, OHIO

BIG JOB...
Bigger results with ROTOBLAST!

Day in, day out, seven heavy duty Rotoblasts work hard at cleaning the tremendous volume of castings produced at a large famous automotive foundry in the Midwest. At last count, each of the seven barrels had accumulated more than 600 hours of actual blast time with practically no need for maintenance or repairs.

Proof of the almost completely automatic operation of these machines is that just two men operate a line of six. (The seventh has a separate location for materials handling convenience.)

Whether your cleaning needs are big or small, Rotoblast has a standard type and size for the job, or specially designed equipment can be provided. Labor-saving automation can be furnished in a small unit just as easily as in seven big ones.

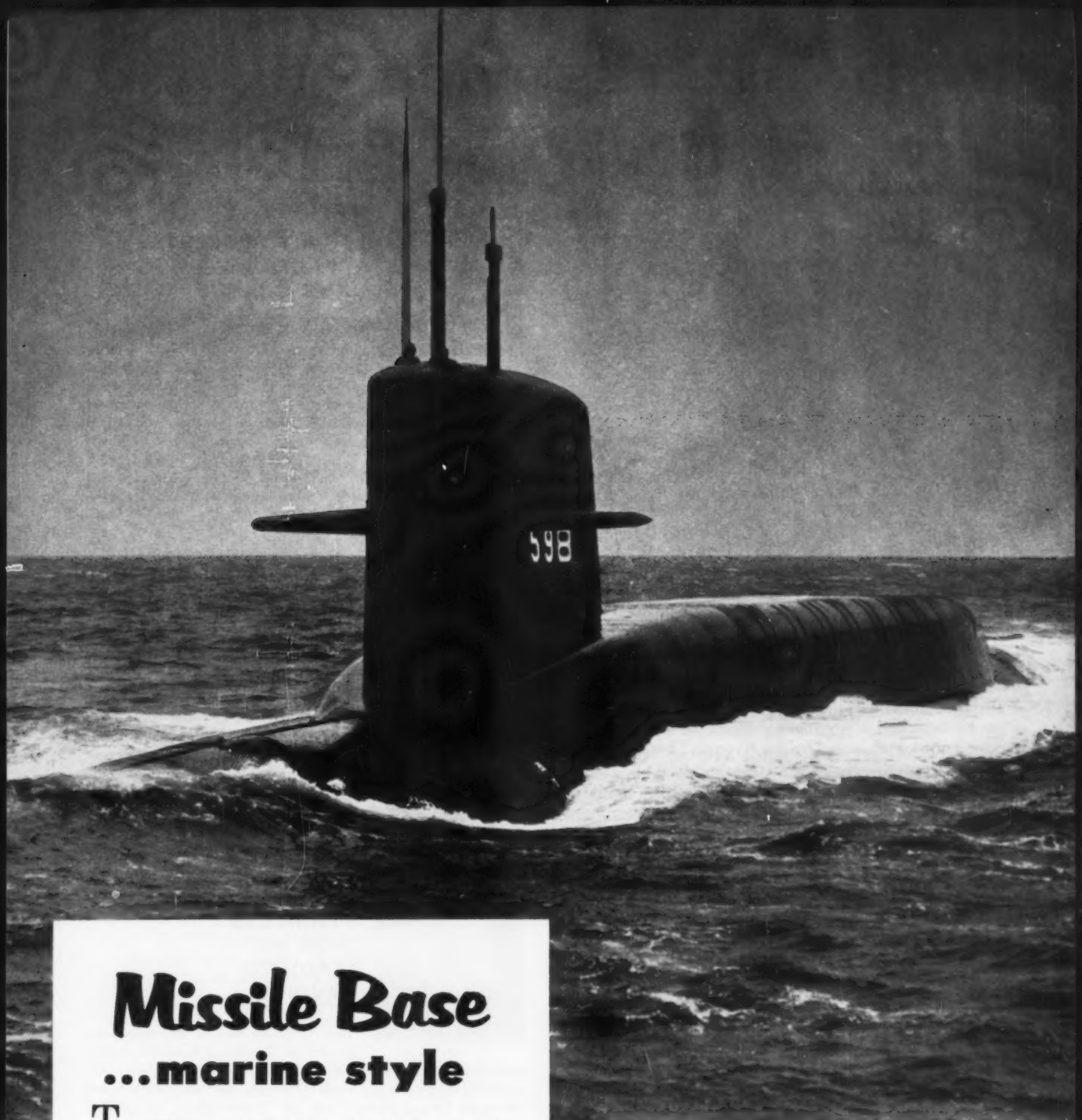
Try Rotoblast abrasives, too!

A special heat-treating process makes Rotoblast Steel Shot and Grit solid, tough, able to take more punishment than ordinary abrasives. Because they are *extra* tough, Rotoblast abrasives last longer, work harder and lower your replenishing costs. We'll be glad to go into more detail. Just write:

PANGBORN CORPORATION, 1800 Pangborn Blvd., Hagerstown, Md.; Pangborn Canada, Ltd., 47 Shaft Road, Toronto (Rexdale), Canada—*Manufacturers of Blast Cleaning, Vibratory Finishing, Dust Control Equipment; Rotoblast® Steel Shot and Grit®.*

Pangborn
OF HAGERSTOWN

Circle 1112 on Page 48-B



Missile Base
...marine style

The USS George Washington is the Navy's first submarine equipped to fire the Polaris missile from submerged positions.

Like the Patrick Henry, Nautilus, Triton, Sea Wolf and other nuclear-powered submarines, the George Washington contains equipment fabricated from stainless steel plate produced by Carlson.

It will be to *your* advantage to specify Carlson stainless steel plate and plate products. Our specialists produce exactly what you want and deliver it to you on schedule. Contact Carlson now.

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Circle 1113 on Page 48-B

PORTABLE "SERVICE CENTER"
sparks new ideas and savings

Hundreds of companies have saved money, improved products and cut production waste as the result of opportunities presented by the Ryerson "Metalogikit."

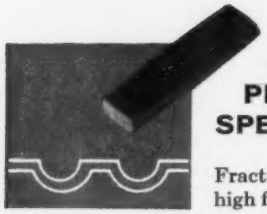
How? This unique kit is a veritable portable service center . . . lets you explore many alternatives to material you now use. For example, you can compare several different cutting methods on the same piece of steel to see which is best for your application.

Following are a few random examples showing how Ryerson specialists, using the "Metalogikit," have helped customers with a variety of problems—many similar to those you may face every day.

If you would like to put the Ryerson "Metalogikit" to work for you, call your Ryerson representative for a demonstration—for unbiased recommendations on steel, aluminum, plastics and metalworking machinery.

KIT SPOTS SAVINGS

Scratches and grooves normal to cold drawn, seamless tubing caused high manufacturing costs for a company making small, light-wall hydraulic cylinders. The small I.D. had to be honed to eliminate these faults—often too much metal was removed for proper piston fit. A Ryerson specialist suggested a switch to *welded tubing*. Using a sample from his "Metalogikit," he pointed out the better finish that eliminates expensive honing. The switch was made with these results: higher production, low reject rate, improved product, lower purchase price per foot of tubing.



KIT SUGGESTS PROFITABLE SPEC CHANGE

Fractures and rejects were extremely high for a manufacturer cold forming two severe bends in flat, hot rolled bars. A Ryerson specialist examined the ⅜" x 2" bar stock and compared it with a sample of M-1020 flattened round bar from his "Metalogikit." He explained how controlled carbon of Ryerson M-1020 bar would produce great cost-saving advantages in this operation over hot rolled, mild steel. After specs were changed to this Ryerson-supplied bar, fractures and rejects were substantially reduced—bringing new profitability.

NEW ANGLES FOR CUTTING COSTS

In making chairs, a furniture manufacturer was using *rolled* aluminum angles in 6061-T6 alloy where strength was not an important factor. A Ryerson aluminum specialist recommended using *extruded* angles in 6063-T5. Using a sample from his "Metalogikit," he pointed out that this angle would provide all the strength needed in the application, is more easily formed and has a better finish. The change in material was made—cutting costs 15¢ per unit produced.

STAINLESS FROM KIT LEADS TO SAVINGS

This company had an emergency requirement for stainless sheets. Application had always called for Type 304, 16 ga. x 66" x 81", *polished on one side*. Their Ryerson specialist questioned the need for polishing. From his "Metalogikit," he showed them a sample of 304 with a 2B finish. The company readily agreed it was exactly the finish needed *without polishing*—saving delivery time and material cost. The Ryerson man further suggested 16 ga. x 72" x 144", using the cutoff pieces for another job—reducing scrap waste on both requirements. Order was placed and delivered in plenty of time. Over-all result: a substantial saving.

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Circle 1114 on Page 48-B

METAL PROGRESS
THE MAGAZINE OF MATERIALS AND PROCESS ENGINEERING
Vol. 80, No. 3 September 1961

GUEST CRITICAL POINT

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Technical Manager,
Department of Metallurgy,
Battelle Memorial Institute

How Should You Evaluate High-Strength Materials?

IN RECENT YEARS, ENGINEERS have become increasingly aware that there is a weight penalty associated with every moving part. For example, it is well known that the weight penalty in missiles is enormous, and that associated with aircraft, very large. But there is also a weight penalty involved with more prosaic items such as automobiles, agricultural equipment, and even ships. Hence, the trend toward lighter and lighter weight, higher and higher service stresses, and, perforce, materials of higher and higher strength.

The materials engineer may with some justification feel he is in a "rat race". He no sooner meets one demand for strength with "adequate ductility" than he is confronted with a new demand for still greater strength – yet "adequate ductility" must remain unimpaired. Perhaps we should pause and take stock. The past may hold lessons that are applicable to the future.

In 1845 wrought iron was the strongest structural material being used for applications requiring reliability in the presence of tensile stress. It had a strength of about 45,000 psi. By 1880, the less-conservative engineers were building bigger and faster locomotives with medium carbon steels which, when normalized, had strengths as great as 75,000 psi. Theirs was not an easy task. These "strong" steels were treacherous. They "crystallized", particularly in cold weather. Since failures of piston rods, drive links and axles were numerous, many engineers concluded that these "newfangled" steels were not practical. Yet, by the end of World War I, we were making and using some components in the Liberty engine that had a strength of 125,000 psi., and these parts were subject to tensile stresses. Progress accelerated, and by World War II a number of aircraft frame and engine components were made from steels that required 190,000 psi. tensile strengths. And today, we are using steels that possess strengths as great as 275,000 psi. Yet, the engineer is still challenged to find stronger and stronger materials. How is he to do this?

What Is "Adequate Ductility"?

Let us first discuss some factors that he must consider. One of the things that is apparent from the past is that our concept of "adequate ductility" has been changing, particularly through the last 50 years. At the time of World War I, metallurgists knew how to heat treat steels to a strength of 250,000 psi.; these steels possessed almost as much toughness as present-day steels with the same strength.

Obviously, progress did not come about because the materials engineer was able to achieve ever-increasing strength while still maintaining a fixed degree of ductility. It is true that the metallurgist has been able to

improve mechanical properties to some degree, but, equally important, the designer has found ways of avoiding stress concentration and the fabricator has found ways of detecting and eliminating flaws in the finished part. Through the years we have learned how to use increasingly brittle materials. Thus, the phenomenal progress of past years has been a combination of *(a)* improved materials, *(b)* improved design, and *(c)* greater perfection in the finished part. As a consequence of these advances, a given material no longer needs the ductility it needed in the past to be "adequate" for the particular application.

As another factor, the concept of transition temperature has become deeply imbedded in our thinking within the last 15 or 20 years. A very helpful tool for evaluating ship plate, heavy forgings, armor plate and a variety of steels quenched and tempered to a strength of 200,000 psi. or less, it will continue to prove useful for these materials for many years. However, as we move to still higher strength levels, the transition-temperature concept places real limitations on prospects for progress.

Figure 1* illustrates how impact strengths change as tensile strengths are increased. Not only does the transition temperature rise with increasing strength, but, more importantly, the energy value of the upper plateau decreases with increasing strength. Thus, at high strength levels, there is less difference between "brittle" and "ductile" fracture in terms of energy absorbed and in terms of deformation prior to fracture. In other words, the transition temperature has less significance at a strength of 280,000 psi. than at a strength of 170,000 psi.

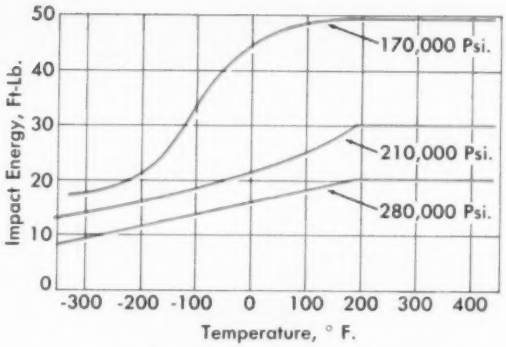


Fig. 1 — Effect of Different Tensile Strengths on Impact Strengths at Various Temperatures. As the tensile strength rises, the transition temperature rises and the energy value of the upper plateau drops. The steel is A.I.S.I. 4340, oil-quenched and tempered

Odd Effects at High Strengths

In addition, some recent experiments have shown that the load-carrying abilities of some notched sheet tensile specimens change in an anomalous manner with the notch severity. Figure 2 shows data obtained on sheet tensile specimens containing centrally located defects of two different degrees of severity. Some of the specimens contained drilled holes 0.1 in. in diameter that produced nominal stress concentrations of about three. Other specimens contained centrally located fatigue cracks 0.1 in. long. In these specimens, the stress concentration prior to the onset of plastic deformation must have been several times greater.

It is not at all surprising, therefore, that the fatigue-cracked specimens failed at a lower load than did those containing a drilled hole. However, it is surprising that, for a given yield strength, the fatigue-cracked specimens of A.I.S.I. 4340 were able to carry greater loads than similar specimens of H11, but that the H11 specimens with centrally located holes were stronger than A.I.S.I. 4340 specimens with the same geometry. Apparently, the order of merit which one might assign to the steel depends to some extent on the degree of stress concentration.

Another way of varying stress concentration is to vary the length of the fatigue crack, the stress concentration prior to onset of plastic deformation being proportional to the square root of the crack length. Figure 3 shows a group of H11 and A.I.S.I. 4340 specimens quenched and tempered to a yield strength of 225,000 psi., but containing fatigue cracks of various lengths. As is apparent, the curves for the two steels cross at a crack length of about 0.05 in. When the cracks are shorter than 0.05 in., H11 will sustain the greater load, but when they are longer than 0.05 in., A.I.S.I. 4340 will sustain the greater load.

Figures 2 and 3 are neither an endorsement nor an indictment of either A.I.S.I. 4340 or H11. That is not the point. The point is that there are subtle differences in steels which the usual evaluation tests will not disclose. Thus, though A.I.S.I. 4340 may seem to be superior to H11 on the basis of either V-notch Charpy tests or

*"The Embrittlement of Alloy Steel at High Strength Levels", by L. J. Klinger, W. J. Barnett, R. P. Frohmberg and A. R. Troiano, *Transactions*, A.S.M., Vol. 46, 1954, p. 1557.

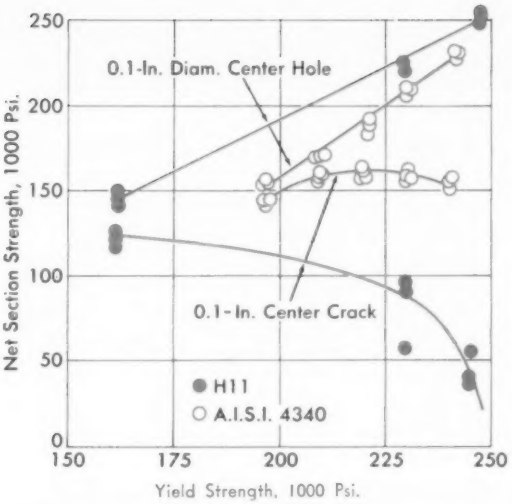


Fig. 2 – Tensile Data for Sheet Specimens Containing Either Holes or Fatigue Cracks, Centrally Located. Note that the H11 specimens with holes appear stronger than the A.I.S.I. 4340 specimens with holes, but that the reverse is true for H11 and A.I.S.I. 4340 specimens which contain cracks. Stress concentration is therefore an important factor to consider in testing metals and alloys

notched sheet tensile tests, Fig. 2 and 3 suggest that such a generalization is not justified.

A Suggested Approach

For the engineer interested in building stronger and lighter structures there is, however, a rational procedure for evaluating materials – one that is consistent with both our present state of knowledge and with the teachings of history. It is necessary to realize that the load-carrying ability of a structure, at least a high-strength structure, is closely related to the stress concentrations which are present. There are two primary sources for these concentrations. One is a matter of how the structure is designed (changes in section size, and the like); the other, in advertent flaws (such as small cracks formed during fabrication, or nonmetallic inclusions formed during casting).

Therefore, it seems reasonable to evaluate high-strength materials by measuring their load-carrying abilities in the presence of the maximum stress concentration likely to exist on the finished part. In some instances, for example, it may be appropriate to use a tensile test with a carefully filleted reduced diameter (when the maximum stress concentration is due to design). More frequently, however, some kind of sharp crack located perpendicular to

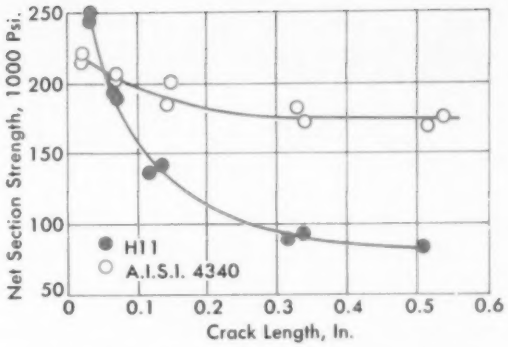


Fig. 3 – Effect of Centrally Located Fatigue Cracks of Various Lengths on Net Section Strength of H11 and A.I.S.I. 4340. Note that H11 appears stronger when cracks are shorter than 0.05 in., but that the reverse is true when the cracks are longer

the applied load will represent the most severe stress condition likely to be present in the finished part. For example, annular fatigue cracks located midway along the length of a standard tensile bar might be used to simulate internal flaws that could not be detected in massive structures. Thumbnail fatigue cracks in sheet tensile specimens might be used to simulate the most severe condition that exists in a solid-propellant motor case. Materials, then, could be rated on the basis of their load-carrying ability (net section strength) in the presence of the stress raiser that seems most appropriate.

Such a procedure would not always be simple and straightforward. To apply it, the engineer would need to determine the type of defect that might exist in the finished part and what the maximum size might be. Second, he would have to realize that the maximum size of defects probably would decrease with improvements in design, fabrication processes, and nondestructive testing technique. Consequently, the kind of tensile test employed would have to be modified from time to time.

On the other hand, such a procedure would have two important advantages. First, if properly executed, it would produce data that could be directly applied to design. Second, it would focus attention on the very important effect that flaws have on the load-carrying ability of high-strength structures.

To sum up, past progress has been the result of simultaneously improving materials, design and fabrication techniques. It should be kept in mind that future progress probably will be the result of joint efforts by the materials engineer, the designer and the manufacturer.

Deformation of Metastable Austenite . . . an Interim Report on a New Process

*By V. F. ZACKAY, W. M. JUSTUSSON and D. J. SCHMATZ**

Rolling Mill and Auxiliary Equipment Used for Studying the Effects of Deforming Metastable Austenite. Temperature and transformation are checked after each pass. In the photo, the operator is inserting a rolled bar into a magnetic coil to determine whether any ferrite is present in the bar

Mechanical properties of alloy steels strengthened by deformation in the metastable austenite "bay" of the T-T-T curve are affected in varying degrees by variations in grain size, tempering temperature, carbon content and other metallurgical factors. Though a good deal of research has been performed, much work remains before the full story is known about this new hot-forming process. (J26p, G-general, Q24; Ay)

TWO YEARS AGO, AN ARTICLE titled "Austenitic 'Cold Working' for Ultra High Strength" (*Metal Progress*, September 1959, p. 66 to 69) outlined some of the results of our preliminary research into the effect of deformation of metastable austenite in strengthening certain steels. Since then, several investigators have devoted much time and effort into finding out more about the potentialities of this interesting new technique. This paper will briefly review some of the recent results concerning process variables and mechanical properties of steels treated in this manner.

To begin with, the process, which is termed "Ausforming", may be described as the plastic deformation of metastable austenite at a temperature within the so-called "bay" that exists in the T-T-T curves of certain alloy steels between the transformation bands of pearlite and bainite, and the subsequent transformation to martensite. In processing, it is essential to control temperatures within strict limits. Because the energy expended in plastically working a metal is largely dissipated as heat, the rate of deformation must be controlled so that the temperature of the steel neither increases so as to form pearlite nor decreases to form bainite. If this is done properly, the structure will still remain completely austenitic when deformation is complete; this will result in a completely martensitic structure upon quenching.

*Mr. Zackay is assistant manager, applied science department, Mr. Justusson is supervisor, research services department, and Mr. Schmatz is research metallurgist, applied science department, Scientific Laboratory, Ford Motor Co., Dearborn, Mich.

Equipment and Processing Techniques

The mill and accessory equipment are shown in the photograph on p. 68. As for controls, after every pass through the mill, the temperature of the workpiece is determined by an infrared-sensing device. Simultaneously with the recording of temperature, the relative degree of isothermal transformation is established magnetically by the use of a Helmholtz coil coupled to a fluxmeter. Since the deformation temperature is normally above the Curie temperatures of the carbides, only ferrite can be detected by this method. In this manner, transformation and thermal histories are obtained and recorded throughout the processing.

The two most important variables are the amount and temperature of deformation. Figure 1 illustrates, for example, the influence of these variables on the properties of a modified H11 toolsteel (Vascojet 1000) containing 0.40% C, 5.0% Cr, 1.30% Mo and 0.50% V. All the

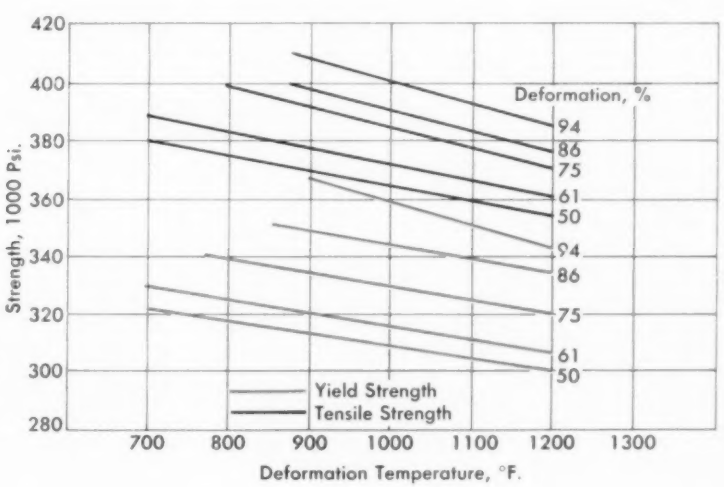
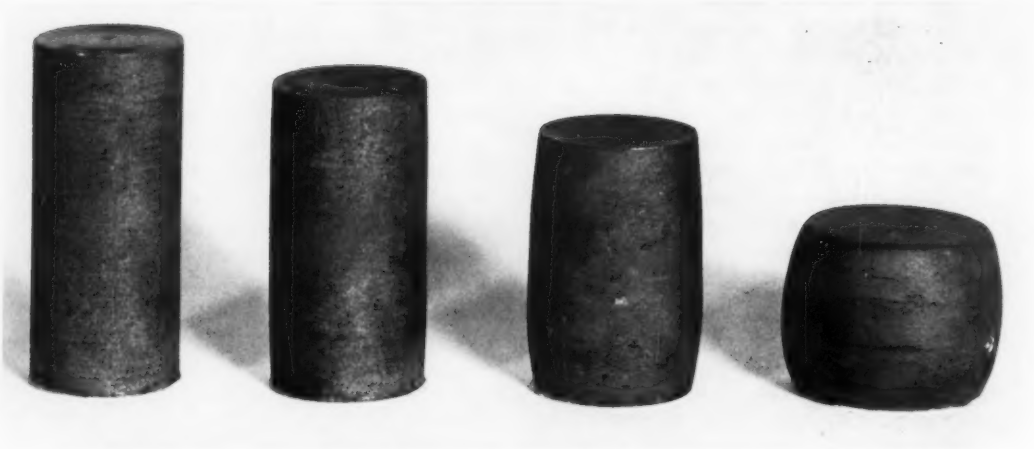


Fig. 1 – How Mechanical Properties of a Modified H11 Steel Vary With Deformation Temperature and Amount of Deformation. As can be seen, a given level of strength can often be achieved by several combinations of processing variables. Tempering temperature, 950° F.



Annealed Original Sample | *Annealed Cold Deformed* | *Annealed Deformed, 1000° F.* | *Austenitized Deformed, 1000° F.*

Fig. 2 – Relative Ease of Deformation of Austenitized and Annealed Cylinders. In each instance, the press load was 60 tons

data shown in this figure were obtained on material which was austenitized at 1900° F. for 1 hr., air cooled to the deformation temperature, deformed by rolling, oil quenched, and double tempered at 950° F. (When not deformed, this alloy in strip form exhibits tensile and yield strengths of 309,000 and 240,000 psi. after tempering at 950° F.) At a given level of deformation, both yield and tensile strengths decreased as the deformation temperature was raised from 700 to 1200° F. Also, for a given deformation temperature, yield and tensile strengths increased with increasing deformation within the range of temperature and deformation investigated. As shown in Table I, ductility also increased with higher deformation temperatures. Because excessive transformations occurred, deformations greater than 61% at 700° F. and 75% at 800° F. were not possible. Instead, the workpiece fractured under those conditions.

Readers will be interested to know that austenite deforms much more easily than does pearlite or bainite at the same temperature. As Fig. 2 shows, the cylinder of austenite has been deformed twice as much as the annealed cylinder at 1000° F., a temperature usually convenient for the process. In each illustrated instance, the press load was 60 tons.

Investigating Metallurgical Variables

During the course of the experimental work, the effects of several metallurgical variables such as grain size, carbon content, tempering temperature, and amount of retained austenite

Table I – Strength and Ductility of Deformed H11 Steel Sheet
(Double Tempered at 950° F.)

Deformation	Deformation Temperature	Strength		Elongation	Reduction in Area
		Tensile	Yield		
0*	—	309,000 psi.	240,000 psi.	7.0%	27%
50%	900° F.	370,000	315,000	7.0	23
86	900	396,000	356,000	8.0	37
94	900	408,000	369,000	9.0	42
50	1200	357,000	300,000	8.0	34
86	1200	377,000	331,000	8.3	38
94	1200	392,000	345,000	8.5	40

*Data supplied by Vanadium-Alloys Steel Co.

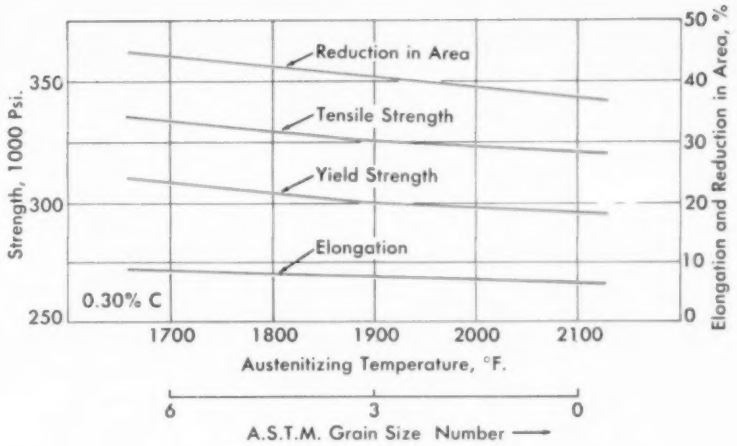


Fig. 3 – Changes in Grain Size Have Little Effect on the Strength of 3% Cr Steel (0.30% C) Deformed in the Metastable Austenite Region. Tempering temperature, 625° F.

were studied. Figure 3 indicates that changes in grain size – from 0 to 6 as rated by A.S.T.M. standards – have but a slight effect on mechanical properties. Variations in carbon content, on the other hand, play as vital a part in determining properties of Ausformed steels as they do in conventionally processed steels. Experimental steels varying from 0.30 to 0.60% carbon were evaluated (nominal composition, other than carbon: 3.00% Cr, 1.50% Si, 1.00% Ni, 0.75% Mn, 0.50% Mo, remainder Fe). As Fig. 4 shows, when the steel is deformed in the metastable austenite region and tempered, its strength is proportional to the carbon content. Ductility, as measured by both elongation and reduction in area, decreased with carbon content as in conventional steels, but reduction in area of steels with over 0.45% C were superior to those of the conventionally treated steels with comparable carbon contents.

The mechanical properties of these steels are usually insensitive to tempering temperature. As shown in Fig. 5, yield strength and elongation values for a 3% Cr steel containing 0.45% C are nearly constant for the range of tempering temperatures above 400° F. However, as with conventionally processed steels, ductility, measured by reduction in area, increases with tempering temperature.

Strengthening Mechanism Is Studied

In the past several years, we have conducted detailed studies in the strengthening mechanism of steels processed by this method. They clearly indicate that the strength of steels which have been deformed in varying amounts and over a wide range of temperatures is largely determined by the amount of cold work retained by the austenite. Prior deformation of the austenite can alter martensite morphology; this may also contribute to the strength. Figure 6 shows a steel containing 24% Ni and 0.40% C. To produce the illustrated structure, the alloy was deformed 50% at room temperature in the austenitic condition, aged at 625° F., then transformed to martensite. In the central region (where the deformation appears to have been the greatest), the martensite plates are severely

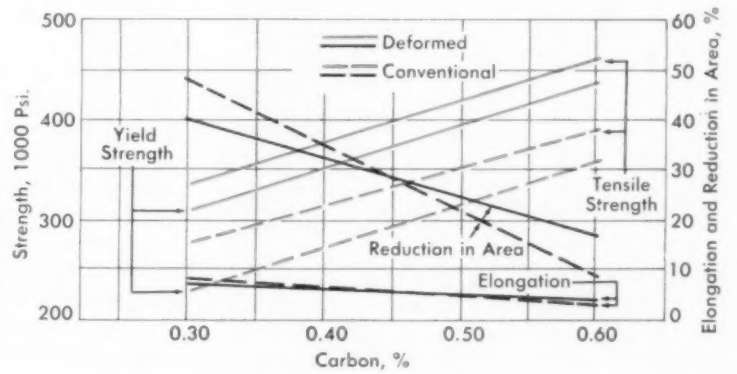


Fig. 4 – Comparison of Mechanical Properties of Deformed (94%) Steels With Those of the Same Steels Conventionally Heat Treated as a Function of Carbon Content. Tempering temperature, 625° F.

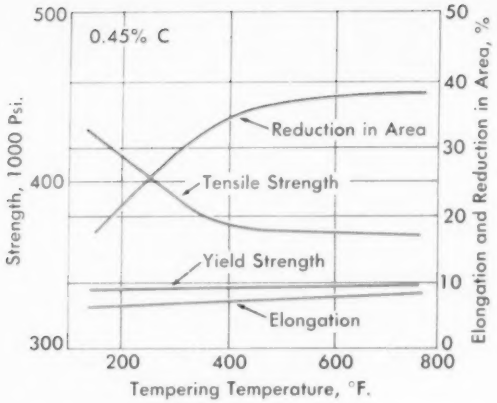


Fig. 5 – Variations in Tempering Temperatures Have Little Effect on the Strengths of These Steels, but Ductilities, as Measured by Reduction in Area, Rise With Increasing Temperatures. For these tests, the specimens were deformed 91% while in the metastable austenite condition

distorted. The parallel sets of dark etching lines running from left to right are slip bands "decorated" with isothermal transformation products formed during aging. Offsets of the martensite plates appear to coincide with the intersecting slip bands.

The amount of retained austenite was determined for a number of steels at various amounts of deformation by a magnetic technique based upon saturation magnetization measurements. For the 3% Cr steels, the amount of retained austenite was virtually independent of deformation. However, with rising carbon content, slopes of the retained austenite-versus-deformation curves increased somewhat. Though the same behavior was also observed for 5% Cr steels, those containing 12% Cr reversed the trend in that increasing deformation appeared to decrease the retained austenite at all levels.

Fig. 6 – Interaction of Martensite Plates With "Decorated" Slip Bands. This steel, which contains 24% Ni and 0.40% C, was deformed 50% at room temperature, aged at 625° F. and transformed to martensite. Etchant: 4% Nital; 500 ×

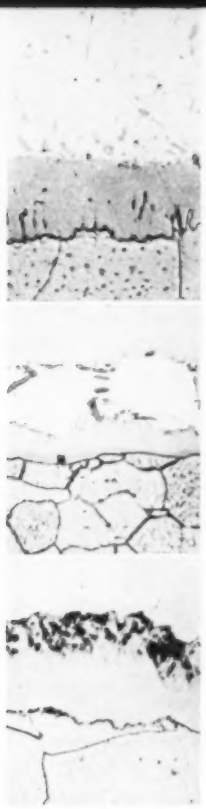
The available data indicate that the percentage increases in strength produced by this processing method are about the same over a wide range of carbon content. However, the precise mechanism by which defects introduced in the austenite may be inherited in the martensite is a subject of considerable speculation; it is being studied in a number of laboratories. Though no evidence is available at present, the use of thin-film transmission microscopy is likely to reveal important data in the near future.

Applications Are Manifold

Since fabrication and heat treatment are simultaneously performed in the process, the greater the diversity of suitable fabrication techniques, the greater will be the diversity of applications. Actually, the method is potentially applicable to any fabrication process which is done at elevated temperatures and in which there is appreciable metal flow. For example, rolling of bar, rod, strip, and sheet; hammer and press forging, both open and closed die; extrusion; and shear spinning have all been employed. Wire drawing and deep drawing of sheet are also under investigation.

Much remains to be done in evaluating properties such as notch sensitivity, fatigue resistance, impact resistance, behavior at very low temperatures, and the like before these steels can take their permanent place. However, there are many promising applications being considered in both the defense and nondefense areas. Some development efforts have already been directed toward prototype production of small-scale rocket casings and aircraft forgings. The known high elastic limit of these steels suggests that they may find use in high strength wire, spring, and suspension applications. In short, it appears that the process can be considered wherever high strengths, accompanied by adequate ductilities, are required.

(References for this article are listed on p. 126)



Prizewinner in 15th Annual A.S.M. Metallographic Exhibit

Microstructures in Aluminized Steel

*By JAMES C. WILKINS**

THE PRIZE-WINNING PHOTOGRAPHS on the next page illustrate the grades of aluminum-coated steel sheets which are produced by the continuous hot-dip process at Armco Steel Corp. Each has specific characteristics. For instance, the grade pictured at the top is coated in a bath of commercially pure aluminum; it has excellent resistance to atmospheric corrosion. The second type (illustrated by the center photo) has a silicon-aluminum alloy coating, and is best suited for high-temperature service and applications where a combination of heat and corrosion is involved. Finally, the bottom picture shows how the aluminum-coated steel sheet (illustrated at top) changes after being heated above 900° F. Though such a coating is not produced commercially, as are the other two, it commonly develops in service at elevated temperatures.

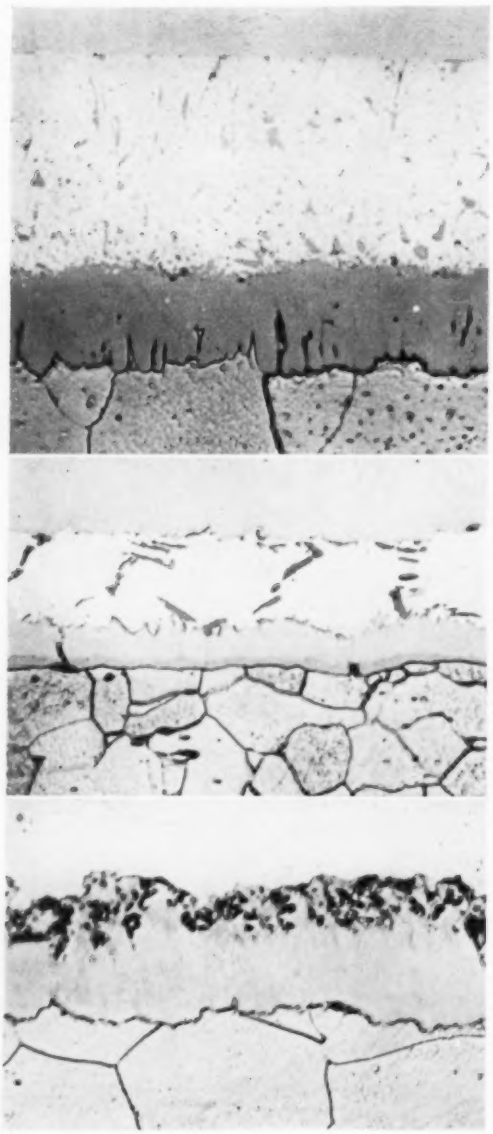
Special metallographic techniques are used to study the coatings on these sheets. Here are the steps we follow. First, four or five samples of coated sheet are bolted together with soft nickel separators placed between each of them. The samples should be bolted tightly, but not tight enough to distort the surface of the coating.

Next, the bolted composite is polished successively with 180 grit, 1, 1/0, 2/0 and 3/0 papers, the direction of polishing being alternated 90° across the same surface with each change in abrasive. A solution of kerosene and liquid wax is used on each of the papers to reduce metal flow. Then the specimens are polished on two AB silk cloths with levigated alumina and AB alpha aluminum No. 2 (each suspended in a soap solution) being employed in turn. After that, we use an AB billiard cloth

*Senior Metallurgist, Research Center, Armco Steel Corp., Middletown, Ohio.

with an AB alpha solution (No. 2) suspended in a soap solution. Finally, we finish the specimen by polishing very lightly to remove fine scratches. For this, an AB microcloth is used with AB gamma alumina (No. 3) in a soap solution being employed for the polishing medium. The sample should be rinsed in water following each wet operation.

As for the etchant, we employ 3% nital (nitric acid in methyl alcohol, absolute). It attacks the grain boundaries of the base metal, outlines the alloy-base metal interface, and gives some contrast to the constituents in the aluminum coating. Since the etchant attacks the base metal, it will remove any film of iron which has flowed over the coating, and a distinct, clear interface will result. Microscopic examination is at 1000 ×, the magnification at which these photomicrographs were taken.



Interpreting the Structures

As stated before, the top micrograph illustrates the sheet coated with commercially pure aluminum. Coating weight is about 1.0 oz. per sq.ft. of sheet or about 0.002 in. of coating on each side. The iron-aluminum alloy layer – it bonds the coating to the sheet steel base – is about 0.0007 in. thick and contains about 45% Fe. The outer layer consists of plates and stringers of an iron-aluminum constituent in an aluminum matrix.

The center micrograph shows the structure of a steel sheet coated with an aluminum-silicon alloy. The total weight of the aluminum is about 0.5 oz. per sq.ft., or about 0.001 in. of coating on each side. Two bonding layers are shown; they represent separate strata of iron-aluminum-silicon alloy. Though the iron content in each of these layers has not been determined independently, the total iron in both layers averages 33.5%. The dark-gray acicular needles in the outer layer are rich in silicon and may also contain a small percentage of iron and aluminum. Small islands (light gray) of an iron-aluminum alloy, dispersed throughout the aluminum matrix are also faintly visible.

The coating produced by the aluminum-silicon alloy is only about half as thick as the other (shown at the top). This difference in thickness is largely due to the effect of silicon. It alters the characteristics of surface oxide of the coating bath and changes the apparent viscosity of the aluminum. This effect, combined with the inhibition of growth of the iron-aluminum alloy layer, results in thinner coatings.

As the bottom micrograph shows, the aluminum coating begins to alloy with the steel base when the sheet is heated above 900° F., thus forming a tight, refractory layer of iron-aluminum alloy. This alloy, which is developed during service at elevated temperatures, has excellent heat resistance and extends the maximum service temperature beyond the melting point of aluminum.

Testing Protective Coatings on Metals

*By PAUL SMITS**

Designed to evaluate anodic coatings on aluminum, a scrape-abrasion apparatus can also be used to test lacquer, porcelain enamel, and other nonconductive coatings. Photoelectric or microscopic equipment is not required. (Q9m; Al, 8-70, 8-71, 8-73)

THERE ARE A NUMBER of tests which evaluate the abrasion resistance of protective coatings on metals. The majority attempt to simulate the type of wear which a coated object may encounter during its useful life.

The abrasive blast technique measures abrasion resistance of anodic coatings in terms of abrasive powder used, or time required to wear through a coating. However, the values obtained are often a function of a number of parameters determined by equipment design rather than coating properties. An additional objection to the use of this test as a production control tool is that the point of failure is not easily detected by the unaided eye. In the "knife-scratch" method – which consists of scraping the same location until the coating is penetrated – results are very erratic because of work hardening of the base metal and accumulated abrasive particles. Furthermore, this test action is seldom encountered under actual service conditions.

A type of abuse not covered by most tests is that of the single abrasive scrape which can occur in actual use. Examples are the exposure of vehicles to flying objects or the scraping of coated aircraft parts by service equipment during refueling or maintenance.

The single-scrape abrasion test in use at Alcan has proven very useful for evaluating coatings on flat metal surfaces, in particular, anodized aluminum. In the test, the coated surface is subjected to a series of scrapes with a pointed tool that moves at a constant speed. Each scratch occurs at a different location. Small increments of weight are added to the tool load between individual scrapes. When the added weight forces the tool to penetrate the coating in one stroke, an electrical circuit indicates failure. The test can be made fully automatic and it is easily performed by untrained personnel.

Design and Operation of Tester

The design principle of the single-scrape abrasion comparator is illustrated in Fig. 1. When testing, a table containing the flat sample moves at a constant speed of 35 in. per min. The pointed tool, attached to the end of a balance arm, moves up and down while the sample passes under it. The tool scrapes the sample over a distance of ¾ in. and is then lifted from it by a profile edge. While the tool is out of contact, an additional increment of weight is automatically added to it by moving a slider over a specified distance on a pivoted balance arm. Weights can be added to the slider to vary the load increment. To increase test sensitivity, slider weight can be reduced to a minimum and a stationary weight sufficiently close to the failure load can be placed directly above the tool.

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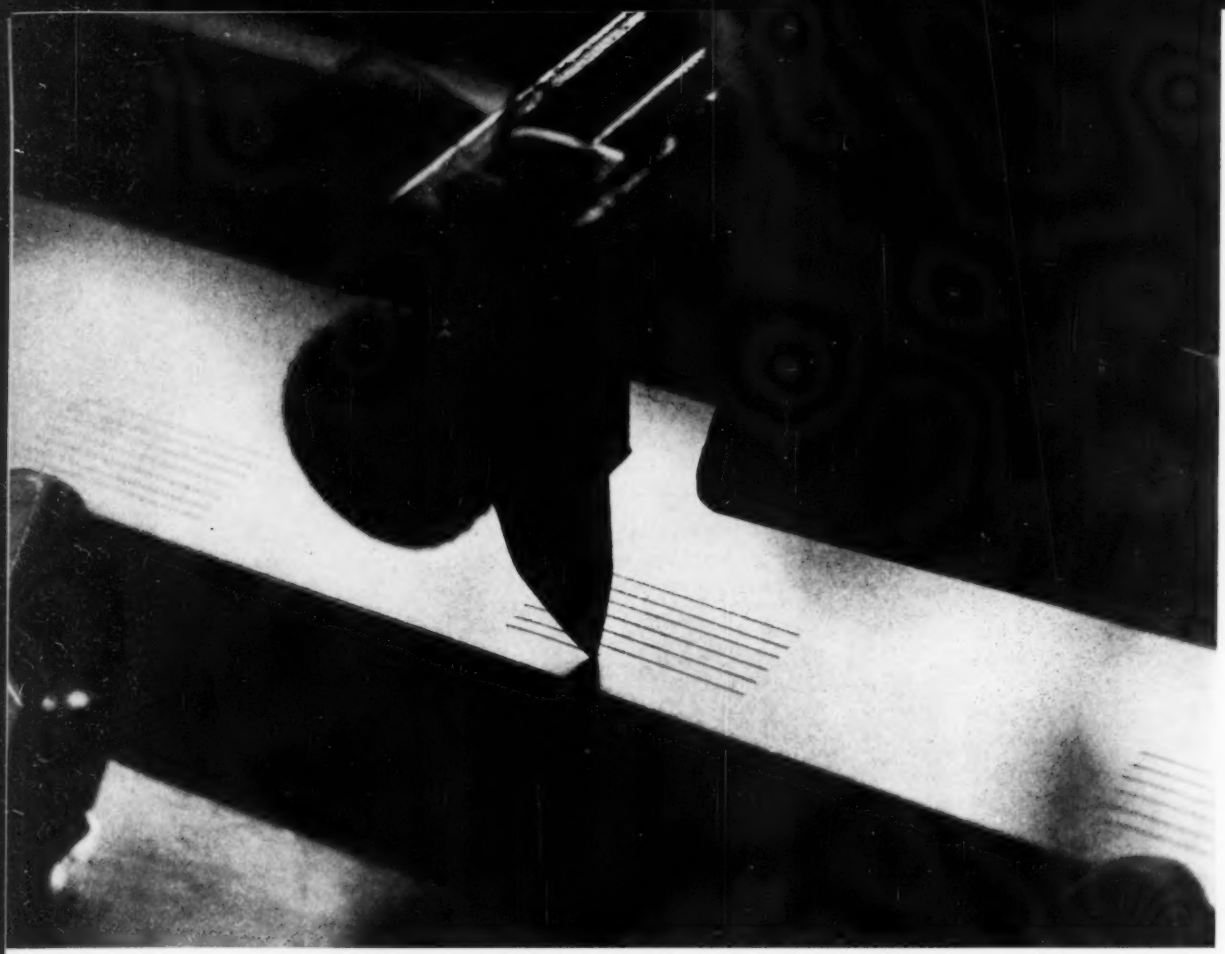
*Aluminum Co. of Canada, subsidiary of Aluminium Limited, Kingston, Ont. The author is indebted to H. T. McLean, General Electric Co., Schenectady, N. Y., who evolved the basic principle, and to P. F. Wade, who assisted with the statistical interpretation.



Close-Up of Abrasive Tester in Action. Scraper tool is made from a standard ¼ in. C5 tool bit

Figure 2 shows a coated metal strip (24 in. by 1½ in.) being tested. At the beginning of each test, the table is moved to one end of the assembly while the arm which carries the scraper tool on its free end is locked in position, preventing contact with the sample. The pivoted arm is then released and properly balanced by means of an adjustable counterweight. As the table begins to move, the tool starts its up-and-down movement, scraping the sample intermittently. When the tool is lifted out of contact by the profile edge, a mechanism along the back side of the table moves the slider on the pivoted arm over a distance of 1 in. toward the free end of the arm.

The load on the scraper tool at the end of the 12-in. arm is $L = \frac{W}{12}$, where W is the weight of the slider in grams, located 1 in. from the pivot. When a stationary weight, C, is placed directly above the tool, the total load (in grams) becomes $L_1 = \frac{W}{12} + C$.

As the testing table moves, the metal surface is subjected to scrape abrasion at this load, L_1. If the tool does not cut entirely through the coating, it is lifted out of contact and the slider moves to a distance of 2 in. from the pivot, increasing the load on the tool to $L_2 = \frac{2W}{12} + C$. A fresh coating area is then abraded at a load of L_2. The operation is repeated as the table moves along, the load increasing in steps up to $\frac{10W}{12} + C$.

When the tool penetrates the coating and an electrical failure circuit stops the tester, the load on the sample is $L = \frac{Wf}{12} + C$, where f is the "failure factor", or distance from the center of gravity of the slider to the pivot in inches. The true abrasion scrape resistance of the sample lies somewhere between $\frac{Wf}{12} + C$ and $\frac{W(f-1)}{12} + C$.

The failure circuit which stops table movement is activated when a current of 0.2 milliamp. is flowing from the scraper tool through

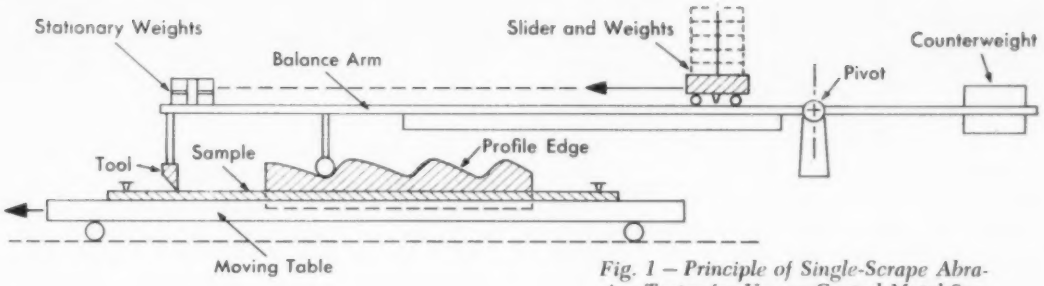


Fig. 1 – Principle of Single-Scrape Abrasion Tester for Use on Coated Metal Surfaces. Weights in small increments can be added to the balanced tool arm

the coated sample, the imposed d-c. voltage being 6 v. The scraper head is connected to the circuit through the scraper arm and its pivot, whereas the sample is connected to it by a sharp pin leading to a sliding contact attached to the table.

After failure of the sample, the table is returned to its initial position. If failure does not occur within the length of the balance arm, a limit switch stops the test. The next test is performed after moving the tool sideways by means of a worm gear. About 16 to 20 test series can be performed on a metal strip 1½ in. wide.

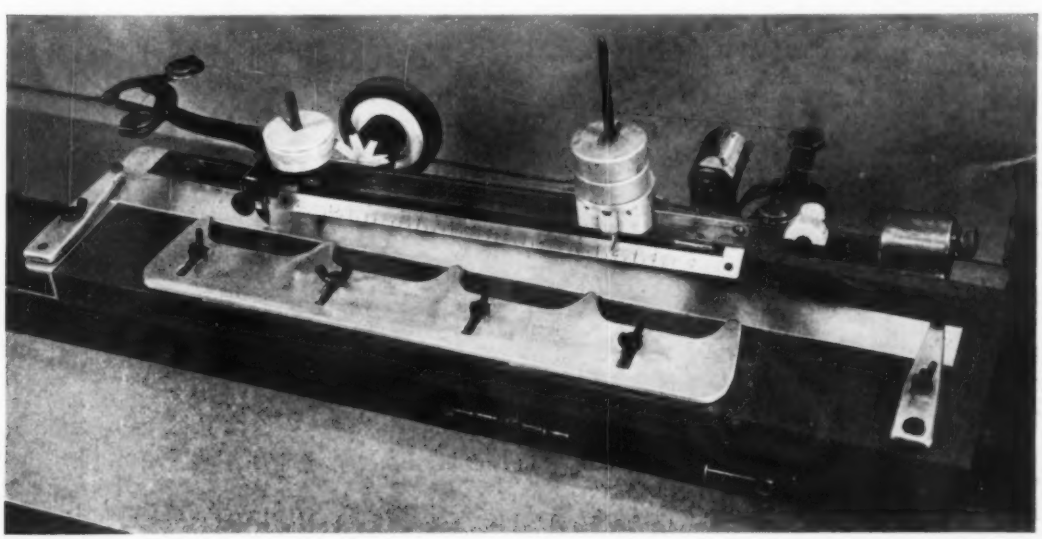
Testing Applications Are Numerous

The test can be applied to a variety of coatings on aluminum and other metals. It has been used with success on lacquered, painted and porcelain enamel coatings, although the latter presents a challenge to the sturdiness of the test apparatus. Our equipment was taxed to the limit of its rigidity when employed on porcelain enamel coatings 4.5 mils thick. The slider had to carry weights up to 3000 g., and the drive motor and toolholder were loaded to capacity. However, there is no reason why a heavier machine could not be built for testing thick, hard coatings.

The table below shows the coatings (on aluminum strip) which the instrument was able to test with adequate reproducibility.

Coating	Thickness	Abrasion Value
Porcelain enamel	4.5 mils	2500 g.
Anodic	1.2	1020
Anodic	0.9	630
Anodic	0.6	450
Paint	1.0	260
Lacquer	0.15	145

Fig. 2 – View of Movable Table and Sample Strip Under Test Showing Scraper Tool and Weighted Slider in Middle and Counterweight at Right



Choice of Load Increment

The value of the increment between two successive scrapes is $I = \frac{W.}{12}$ It can be minimized by using the slider alone. However, there is a practical limit to this reduction. It is reached as soon as failures tend to occur outside the range indicated by the balance arm. It is assumed that the stationary weight, C, at the end of the balance arm has been chosen sufficiently close to the true average abrasion value so that the majority of failures occur at or near the center of the balance arm.

For anodic films on aluminum, 0.3 to 1.2 mil thick, it was found that all test values fall within a range not exceeding 30% of the average. The load increment should not be chosen as large as this spread since all failures could occur at one point which would result in a precision as poor as ±15%. As the increment is reduced, the precision of the average value is improved, although individual failure points are scattered more along the balance arm. A limit is reached when the increment is chosen so small that failure would occur outside the end points. For anodic films, this happens when the increment amounts to about 5% of the expected average failure load. Based on this, the stationary weight (in grams) to be placed at the end of the balance arm is $C = \frac{(20 - f)W,}{12}$ where W represents total slider weight. The distribution of failure values is generally symmetrical. To guarantee that all failures will fall within the end points, one should select weight relationships (between C and W) so that the majority of failures occur near the middle of the available distance on the balance arm. This distance, f, is 6 in. for a 12-in. arm. Substituting this value in the above equation, $C = \frac{14W}{12}$.

Summing up, if a specimen of unknown abrasion characteristics is to be tested, the procedure would be as follows:

1. Locate roughly the range of abrasion values by choosing a rather large increment and performing several tests.

2. Choose the load increment $I = \frac{W}{12}$ as 5% of the average failure load and make the slider weight 12 times this increment or 60% of the expected average.

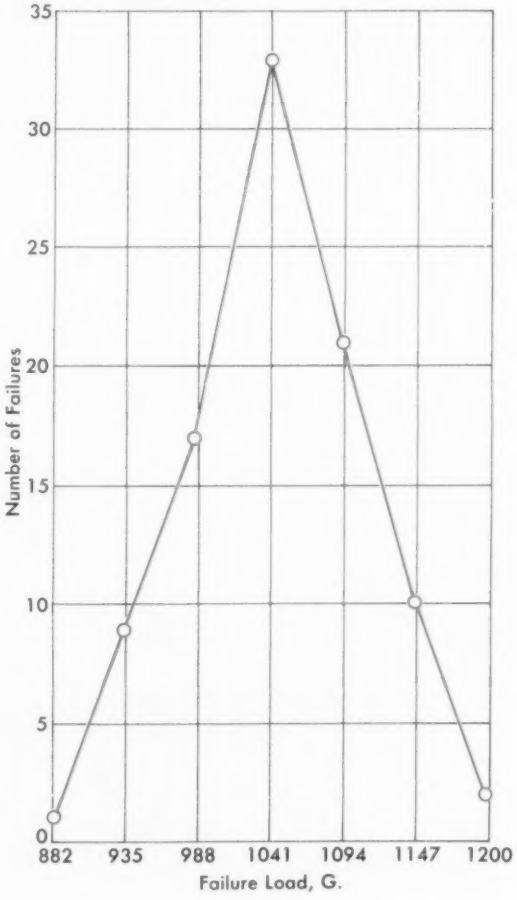
3. Choose the stationary weight, C, as outlined above.

4. Make small adjustments to the added weights so that no failures occur at the first stop and none beyond the final position of the slider.

Reproducibility

According to statistical theory, if the average failure load is required with a precision of ±p (95% confidence), the number of tests to be performed is $n = \frac{4(\sigma_s)^2}{p^2}$ where σ_s is the standard deviation for a single test result. Figure 3 shows a typical distribution of 93 test values obtained on a 1.2-mil thick anodic film (I = 52 g.). When the data are plotted cumulatively on normal probability paper, the standard deviation of a single test result, σ_s, can be approximated as half the range of failure loads containing 70% of failures (Fig. 4). For 99.8% bright aluminum panels anodized under similar

Fig. 3 — Distribution of Abrasion-Scrape Values Obtained in Testing a 1.2-Mil Thick Anodic Coating on Aluminum



conditions (15% H_2SO_4, 15 amp. per sq.ft., 70° F.) and for coating thicknesses between 0.6 and 1.2 mil, σ_s has been found to amount to 6% of the average failure load.

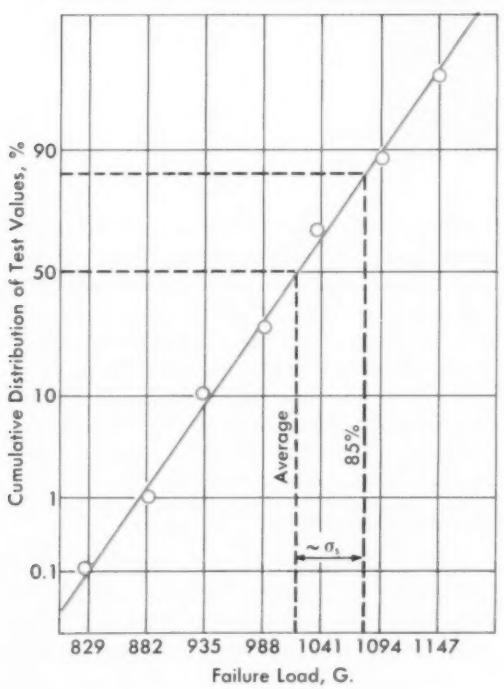
As an example, to determine precision within ±4% would require:

$$n = \frac{4(6)^2}{4^2} = 9 \text{ tests}$$

Once the average failure load is determined from n test results, the true average abrasion-scrape resistance of the sample is obtained by subtracting one-half increment from this value. This is due to the positive bias of each single test as the true abrasive scrape value is somewhere between the point where the sample failed and the prior point. However, if the average is obtained from a cumulative distribution, as in Fig. 5, this constant bias is automatically corrected.

Because of the influence of "rounding" introduced by the fixed increment, normal statistical techniques should not be used when n is less than 7 (assuming an incremental weight of 5% and a σ_s of 6%). For estimates of high precision, a smaller increment is desirable – of the order of $\frac{\sigma_s}{4}$. This may be achieved by building an apparatus with a much larger arm and choosing a very fine increment of, say, 1% of the expected average value.

Fig. 4 – Cumulative Distribution of Values From Fig. 3. The standard deviation of a single test, σ_s, is estimated as half the range of failure loads containing 70% of failures, that is, the range between loads below which 50% and 85% of all samples have failed

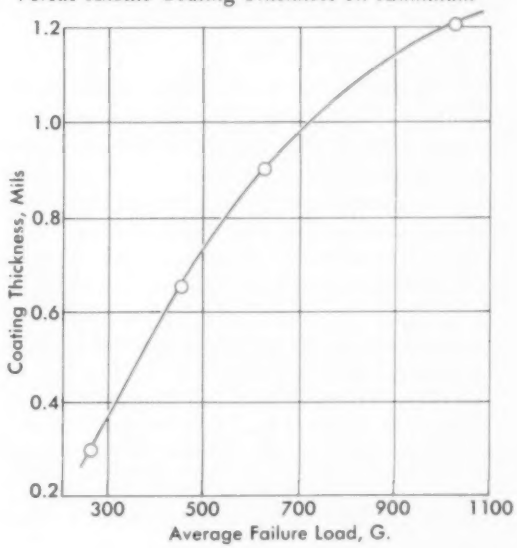


Sensitivity

If the test is to be useful at all, it should be able to discriminate between relatively small differences in abrasion-scrape resistance that may be caused by variation in coating thickness, hardness, density, or composition. It can be shown that, for two different samples, approximately 31 tests per sample are required to distinguish between real differences which are less than 10% and those greater than 15% (95% confidence level). In some instances, there is a clear relationship between certain coating properties and the average abrasion-scrape resistance measured, as shown in Fig. 5. Thus the instrument can be used as a quality control tool for anodic coatings or paint coatings on aluminum sheet.

If regular tests are performed on coatings produced under stable conditions, the abrasion comparator may be set up in such a manner that with a selected increment all failure values occur within the limits of the balance arm. As soon as failures begin to take place outside these limits, a change in production conditions has occurred and corrective action should then be taken.

Fig. 5 – Average Abrasion-Scrape Resistance Versus Anodic Coating Thickness on Aluminum



Designing a Weldable Alloy Using Metallurgical Parameters

*By W. N. PLATTE**

The general aspects of developing alloys for weldability involves metallurgical and physical data. These parameters are applied to the design of weldable molybdenum alloys. (K9s; Mo-b)

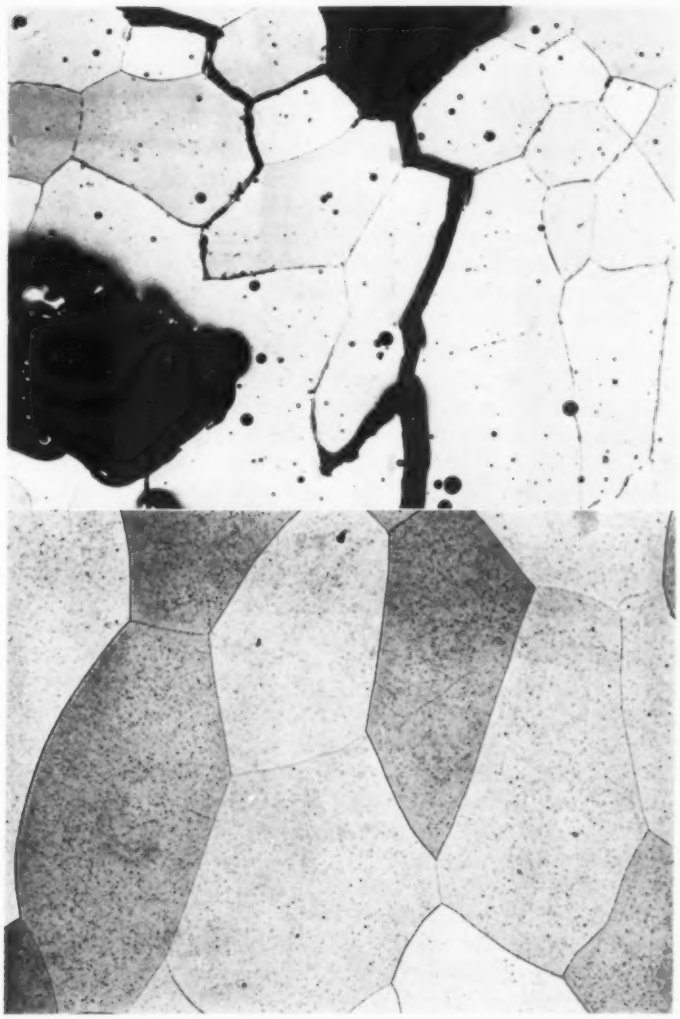
THE CONCEPT OF DESIGNING MATERIALS for welding is relatively new. Previously, alloys were specified, their properties determined, and a welding technique developed to join them. Unfortunately, this approach frequently led to serious welding problems since the base material was often the source of welding difficulties. Thus, to obtain the maximum usefulness from a material, it should be designed to accomplish its structural intent without impairing its welding properties.

Studies of molybdenum-base alloys have afforded an opportunity to develop metallurgical design parameters for weldable alloys. Molybdenum was subject to most of the serious welding defects, that is, hot cracking, porosity, and loss of ductility at temperatures near ambient. These properties made molybdenum an excellent subject for study in developing weldability parameters. Furthermore, the relative simplicity of the alloy systems made examination of fundamental problems possible.

*Research Engineer, Metals Joining Section, Metallurgy Dept., Westinghouse Research Laboratories, Pittsburgh. The molybdenum welding portion of this work was done under U.S.A.F. Contract AF33(616)-3524.

Important Metallurgical Parameters

The conditions encountered by a welded material must be understood before metallurgical data can be used intelligently as weldability parameters. The weld metal must be heated, melted and solidified while bonded to a mold



Not Deoxidized

Deoxidized

Fig. 1 – Effect of Deoxidation on Molybdenum Welds. Deoxidation practice, established during development of fabricating techniques for molybdenum, also is important in insuring good weldability. 100 ×

of its own base material. The severe temperature gradients, cooling rates, and stresses implied by these conditions are obvious. Furthermore, recrystallization, grain growth, resolution and precipitation may occur during welding in addition to melting and solidification.

Fusion and solidification of weld metal present problems in coring, grain-boundary segregation, and gas evolution. Due to low-melting-point eutectics, material in the grain boundaries may be molten or have low strength when stresses due to cooling are increasing. This condition will produce cracking. Gas porosity in welds occurs because of changes in solubility or volatilization of components at the melting point of the alloy.

To provide a material which is capable of withstanding the temperatures and stresses encountered during welding, metallurgical property data must be found which indicate the material's strength, resistance to cracking, ductility, and tendencies toward porosity over the entire temperature range. The selection and interpretation of metallurgical data to develop a weldable material constitute a method of weldability prediction and alloy design.

Weldability parameters may be divided into two groups which involve high and low-temperature properties and events. High-temperature welding parameters involve phase equilibrium data and include the melting points of all the alloy constituents and phases. Special attention is given to phases or eutectics with melting points which differ widely from the

base composition. Welding is a nonequilibrium process, and coring may place low-melting-point materials or phases in the grain boundaries. Such segregation can be a prime source of cracking. Segregation effects should be considered both for the principal alloying elements and for inherent impurities. The melting point, decomposition temperature, and vapor-liquid equilibrium data of the elements, compounds, oxides, and nitrides possible in the system must also be examined so that gas evolution can be prevented.

Frequently insufficient data exist or the equilibrium diagrams are so complex in multicomponent systems that they have only been partly determined. Under these conditions, use is made of forging and rolling characteristics which indicate boundary weakness or "hot short" conditions on the initial breakdown of the cast ingot structure. High-temperature creep, tensile, stress-rupture, "hot ductility", and "cast-pin tear" test data can be helpful in predicting damage which may occur during welding.*

Tolerance for boundary impurities is related to the grain size. Since the grain size of the weld metal is partly determined by base-metal grains which nucleate the solidifying weld metal, data on recrystallization temperatures and grain growth characteristics are helpful in estimating weld properties.

The second parameter group involves low and intermediate-temperature properties and events such as phase changes in the solid state, precipitation, ductile-to-brittle transition, final grain size, strength, and ductility. Strength and ductility data at all temperatures are useful in predicting the response of the material to the thermal stresses which occur during welding. Thermal expansion and conductivity data indicate the degree of stress expected at any temperature. Ductile-to-brittle transition data and mechanical properties at intermediate temperatures indicate the effects of residual welding stresses encountered prior to and during postweld heat treatment.

It is apparent that the parameters used in predicting weldability and designing weldable alloys involve many properties examined during the metallurgical development of an alloy. Hence, simultaneous development of service properties and weldability is possible.

*For additional information refer to "Further Studies of the Hot Ductility of High-Temperature Alloys", by E. F. Nippes and W. F. Savage, Welding Research Council Bulletin No. 33, February 1953, and "Cast-Pin Tear Test for Susceptibility to Hot Cracking", by F. C. Hull, *Welding Journal*, Vol. 38, April 1959, p. 176-s.

Parameters Applied to Molybdenum

The welding and material requirements for each new alloy vary, and the methods of applying the weldability parameters must be modified to fit each particular case. An early attempt to weld molybdenum using the inert-gas tungsten-arc technique produced the result shown in Fig. 1. The porosity and cracking were so severe that the loss of ductility which occurred at low temperatures was academic.

Work on arc-cast molybdenum alloys† showed that, if the ingots were to be fabricated, the material must be deoxidized. Improvement in weld quality due to deoxidation is shown in Fig. 1. This improvement involved the weldability criterion which applies to hot cracking in the ingot breakdown stage. Thus, the development of an alloy capable of hot reduction from the cast stage is also the first major step in developing a weldable material.

Welding techniques involving carefully controlled atmospheres lowered the ductile-to-brittle transition several hundred degrees as shown in Fig. 2. Exploratory tests indicated that further improvement would have to be obtained by adding alloying elements.

Since extensive metallurgical data are available on a number of molybdenum alloys, it is possible to examine these with respect to the weldability parameters.

Hot Cracking Alloys Eliminated

Hot cracking in molybdenum is most frequently caused by its molten oxide in the grain boundaries. This is typical of metals containing material with melting points lower than that of the bulk metal. One of the problems in designing a molybdenum alloy for welding was to select a deoxidizing agent which would prevent oxide cracking without damaging the welding or mechanical properties.

The properties of successful deoxidizing elements were considered with respect to their effect on molybdenum, using the high-temperature weldability parameters. Many of these strong oxide-forming elements form phases hav-

†"Arc-Cast Molybdenum-Base Alloys", by M. Semchyshen and R. Barr, Summary Report to Office of Naval Research, Contract N80nr78700, Climax Molybdenum Co., 1955.

ing low melting points with molybdenum and can not be used. The melting points of the oxides and nitrides of the deoxidizers were examined, and those with fusion points lower than molybdenum were eliminated. Ultimately, all the elements except carbon, titanium, aluminum and zirconium were rejected. Of these elements, the oxide of carbon is volatile and is removed during the initial arc-casting process. Titanium forms a continuous series of solid solutions with molybdenum, but its oxide melts at a fairly low temperature relative to molybdenum. However, titanium oxide forms small spheres in molybdenum and does not damage the weld metal. Aluminum is a successful deoxidizer, but it and its nitrides are volatile at temperatures below the melting point of molybdenum. Aluminum also forms a eutectic with a low melting point. Hence, additions of aluminum were limited to 0.2 to 0.3%. The data on zirconium alloys were insufficient to predict the welding properties, but these alloys were examined to gain information on weldability.

Alloying elements added for purposes other than deoxidation were considered with respect to their effect on hot cracking. Known systems were examined for eutectics, oxides and nitrides with low melting points. Where equilibrium data were not available, the rules of Hume-Rothery were applied. Many of the elements added to improve the mechanical properties of molybdenum were rejected because they form low-melting-point constituents which have limited solid solubility and could cause difficulty due to grain-boundary coring. Nickel, iron, cobalt and beryllium are in this category. Included in a borderline group are boron, carbon, aluminum and zirconium which have high solid solubility at their eutectic or peritectic temperatures compared to the intended additions. The use of boron appeared to be too critical since the amounts involved were extremely small. The elements not eliminated because of hot cracking were titanium, aluminum, carbon and zirconium.

Prevention of Porosity

The principal source of porosity in molybdenum is the oxide which is removed by deoxidation. However, the elements not eliminated for hot cracking tendencies were examined with respect to their boiling points and the boiling points of their oxides and nitrides. Titanium and zirconium are satisfactory; the vapor pressure of aluminum and its nitrides are high; and the product of deoxidation with carbon is a gas. If deoxidation is complete before welding, carbon should be satisfactory. Aluminum may cause some porosity, but in the amounts added, 0.2 to 0.3%, porosity should be slight.

The mechanical properties of molybdenum weld metal may be improved by alloying elements which increase the strength and ductility and reduce the grain size of the weld metal. The grain size of the weld metal is a function of the grain size of the base material at the fusion interface, and it may be reduced if the grain size at the interface can be decreased.

Data show that aluminum, titanium, zirconium and columbium raise the recrystallization temperature. Of these materials, zirconium and titanium were the most effective. Aluminum is also effective but additions of about 1% are required and this amount would cause hot cracking and porosity. Alloys containing columbium have a high recrystallization temperature, but columbium forms a low-melting oxide, and difficulty due to hot cracking was anticipated. Titanium additions increase the recrystallization temperature most rapidly up to 0.5%.

Examination of those alloys not already eliminated indicated that alloys with aluminum demonstrated the smallest amount of grain growth. The effectiveness of aluminum starts in the region of 0.2% and increases with the alumium content. Difficulties with aluminum in amounts over 0.3% have already been mentioned. In general, minimum weld grain size possible without damage to weldability should be obtained with alloys containing 0.2% Al and 0.5% Ti.

Mechanical and Thermal Properties

The lowest impact transition temperature was found in alloys containing 0.45% Ti and 0.08% Zr. In tension, the lowest transition temperatures were obtained in the following alloys: 0.006% C, 0.12% Al, 0.5% Ti; 0.02% C, 0.45% Ti; 0.014% C, 0.22% Ti; 0.003% C, 0.15% Al.

It was found that the titanium and the zirconium alloys had the best room-temperature tensile strength indicating that they could resist residual stresses at a higher level.

An examination of the high-temperature tensile and creep data showed that alloys of vanadium, cobalt and nickel had the best properties. However, all of these alloys were rejected for poor weldability. Alloys containing titanium

showed good high-temperature properties.

The coefficients of thermal conductivity and expansion showed that the thermal stresses would probably be the highest in molybdenum-titanium alloys. However, the other properties of these alloys justify their use regardless of less desirable thermal characteristics.

Final Selections

It became increasingly evident from the data on arc-cast molybdenum that the elements which are most useful as deoxidizers and as alloying elements are titanium, aluminum, zirconium and carbon. Conflicting data existed concerning the effects of carbon on the ductility of molybdenum welds. Transition temperature data showed that ductility improves at low temperatures when the carbon is decreased. However, welding tests showed a reverse effect. Hence, the effects of carbon were examined experimentally.

Alloys with titanium in the 0.5% range are most promising. Alloys containing zirconium and aluminum in the amounts 0.05 to 0.1% and 0.1 to 0.2%, respectively, should be weldable. The addition of carbon in conjunction with other elements depends on the element with which it is used.

Welding Tests Made

Molybdenum-base alloys were procured covering composition ranges indicated by the design parameters. The alloys were examined by making fusion weld beads in plates without added filler material. Welds were tested in bending over a range of temperatures to locate the ductile-to-brittle transition. Test results are compared with data obtained using unalloyed material deoxidized with carbon.

The studies on the effect of carbon indicate that it acts as a protective deoxidizer and improves the ductility of the welds by reducing

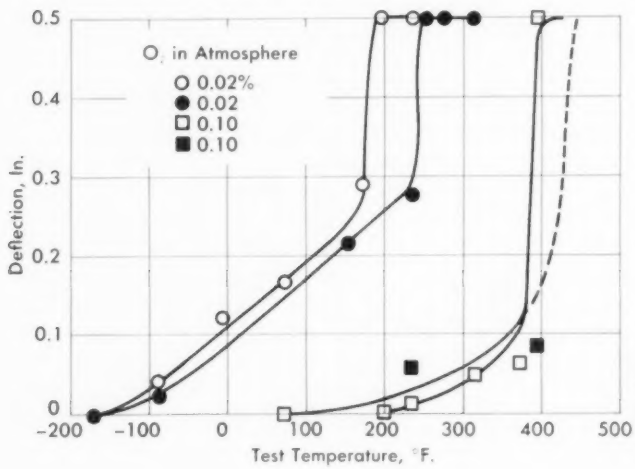


Fig. 2 – Influence of Oxygen in the Welding Atmosphere on Bend Ductility in Molybdenum Welds Deflection of 0.500 in. is equal to 120° bend

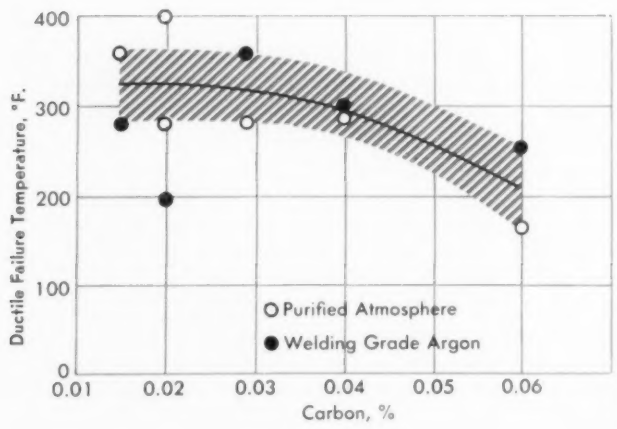


Fig. 3 – Influence of Carbon on Temperature of Ductile Failure (0.500-In. Deflection, 120° Bend) in Molybdenum

the oxygen content of the metal as shown in Fig. 3. With the effect of carbon established, it was possible to examine the influence of titanium, aluminum and zirconium.

Welding tests made in the alloys selected showed that they were free of the gross hot cracking and porosity shown in Fig. 1. However, the alloys containing aluminum showed fine porosity as predicted by the design parameters, that is, aluminum and aluminum nitride boil at temperatures below the melting point of molybdenum. Metallurgical examination of the welds showed that the alloys with fine-grained weld metal were those with high recrystallization temperatures and slow grain growth rates.

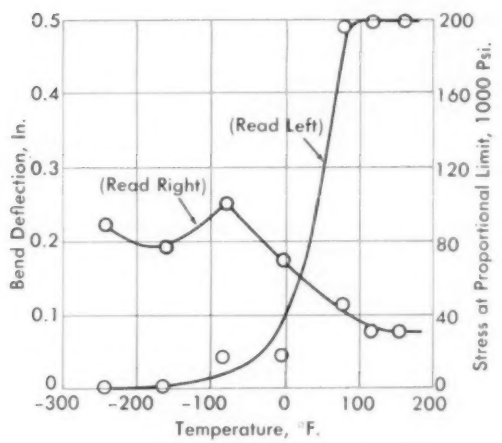


Fig. 4 – Bend Test Data for Welds Made on Molybdenum Deoxidized With 0.20% Al. Because of high vapor pressure of aluminum, this alloy contains fine porosity when welded

The temperature for ductile behavior in bending in carbon-deoxidized material is between 200 and 300° F., as indicated in Fig. 2 and 3. The alloys containing between 0.18 and 0.20% Al were ductile at 80° F., as shown in Fig. 4. Welds in the 0.5% Ti alloys showed their best behavior when 0.05% C was added. They were ductile at 80° F. (Fig. 5) and were not porous. The welds in the alloys containing zirconium were free of cracking and porosity; however, the ductility in bending was not improved over the results obtained in the carbon-deoxidized material.

The tensile strength of the weldable alloys is indicated by the stress at the proportional limit in bending. The proportional limit for the selected alloys was improved over the carbon-deoxidized material by a factor between 30 and 75%, as shown in Fig. 4 and 5.

Frequently welds in carbon-deoxidized molybdenum crack after cooling because of residual stresses and the loss of ductility at room temperature. The alloys which showed ductile behavior at 80° F. and improved strength were not subject to this form of cracking.

Summary

Alloys selected using the design parameters were free of the welding defects normally found in molybdenum. The ductility of the alloys was greatly improved over the carbon-deoxidized material, indicating a successful improvement in the ductile-to-brittle transition temperature. The fine porosity found in molybdenum-aluminum alloys confirmed the parameter involving volatile materials.

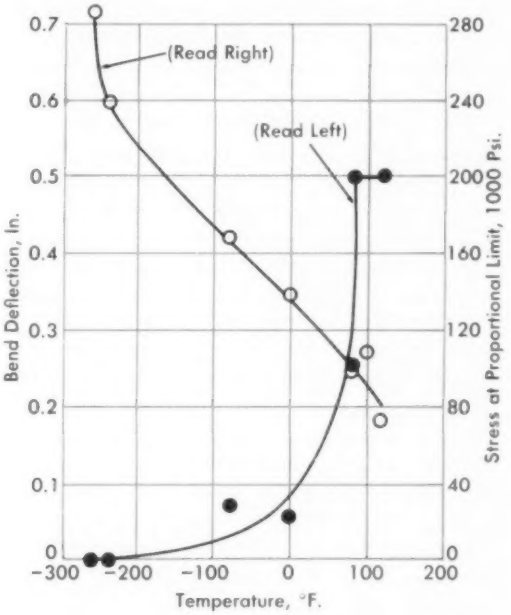


Fig. 5 – Bend Test Data for Welds Made on Molybdenum Alloy Deoxidized With 0.5% Ti and 0.05% C. This alloy is strong and ductile and when welded it does not crack or become porous

While the approach used here was based on the properties of molybdenum, the general method of determining weldability can be adapted to other materials. However, individual treatment will be required. As our skill in the use of weldability parameters increases, welding problems will be reduced.

*The Promise of the Atom**

ULTIMATELY, NUCLEAR POWER will be an absolute necessity. Although this country and the world have relatively abundant supplies of fossil fuels, they are far from limitless. There are two approaches to the power problem — through fission and through fusion. The first seems far more certain and must clearly be pursued. We must develop a technology incorporating large-scale nuclear power in such a way that we realize the full potentiality of the world supply of fissile materials. Hence, breeder programs utilizing both the thorium and the plutonium cycles must be pressed with due diligence.

The long-range program must include research and development leading toward new, more efficient and less costly systems. It must be bold and have imagination. It must seek step-wise advances in technology and in the systems concepts. An important research area lies in solid-state physics and metallurgy. A fundamental understanding of the solid state is needed as a basis on which to develop new and improved materials. Limitations on the ability of our present materials to withstand heat, cold, chemical reactions, radiation and physical stresses now place limitations upon our technological progress in many areas.

Much work remains to be done in investigating nuclear spectrums and nuclear reactions in the low-energy range before we will have a thorough understanding of complex nuclei. Of special interest are such fields as neutron-induced reactions and work with the transuranium elements.

Since the vital need for large-scale nuclear power is fairly far in the future, it is often asked, why a power program now? There are many reasons. The most obvious is that in all technologies, full-fledged practical advancement is achieved through many generations of successively improved devices. Our cars, our airplanes, and our present power stations give ample illustration.

Hand in hand with this requirement must be the growth and learning of the nuclear industry itself. It must gain a broad experience in building and operating nuclear power stations with the attendant problems of health and safety and of waste handling and disposal.

In our preoccupation with the application of reactors to civilian power, we must not forget their many other potential uses. In the industrial field these include process heat and the possibilities of using reactor radiation for inducing chemical reactions on an industrial scale. Another important future application is in the space program where reactors have great potentialities, both for large-scale auxiliary power and for propulsion purposes.

In another, though related, field, we should continue to press developments looking to the use of radio-isotopes. Their potential applications as tracers are almost limitless in basic research, in industrial processes and in such important geophysical fields as meteorology and studies of our natural water supply.

The energy available from reactor products will in time be enormous. We must do our best to utilize it both in direct radiant form for such purposes as pasteurization, sterilization, and to promote chemical reactions, or reduce it to thermal energy for industrial heat and for small-scale power generation. To take a single example, thermal electric power sources have almost limitless applications for such things as remote weather stations, navigation buoys, and, perhaps most glamorously, in satellite and space vehicles.

This huge and complex technical program requires, of course, the combined efforts of many kinds of people in many kinds of institutions. Engaged in the manifold activities are physicists, chemists and metallurgists — chemical, electrical and mechanical engineers — biologists and medical scientists — and many others. They work in many places, in colleges and universities, in national laboratories and in industry. It seems very clear that there is no dearth of work for all.

*Excerpts of remarks made by Leland J. Haworth, Commissioner, U. S. Atomic Energy Commission, before the recent annual meeting of the American Nuclear Society in Pittsburgh.

A New High-Strength Aluminum Alloy

*By J. A. NOCK, Jr., MARSHALL HOLT and D. O. SPROWLS**

Initially introduced as an aircraft forging alloy for highly stressed parts operating at 500 to 600° F., alloy 2219 has demonstrated other outstanding characteristics – good weldability, high strength, and resistance to stress-corrosion cracking – that make it suitable for applications in transportation, missiles and the chemical process industries. (A-general, Q-general, T-general, 17-57; Al-b)

ALLOY 2219, A NEW TYPE OF high-strength aluminum alloy, differs from other high-strength alloys – Al-Cu-Mg and Al-Zn-Mg-Cu – in that it does not contain either magnesium or zinc. The alloy contains copper as the major alloying element and small additions of manganese, zirconium, vanadium and titanium† which are essential for high strength at elevated temperatures. Although the strength of 2219 at 500 to 600° F. – highest of any wrought aluminum alloy (see Fig. 1) – is not being fully utilized now, the ease of welding, uniformity of weld strength, and resistance to stress-corrosion cracking make it suitable for many new fields.

Corrosion Resistance Is Good

In sheet form, the corrosion characteristics of 2219 are similar to those of other high-strength alloys of aluminum, such as 2014 and 2024 (Table I). When the alloy is artificially aged to the T 81 or T 87 temper, the resistance to corrosion or to stress-corrosion cracking is similar to that of 2024-T 6 and considerably superior to 2014-T 6. Corrosion characteristics of the naturally aged T 31 and T 37 tempers are similar to those of 2024-T 3. (In thicknesses of 0.064 in. and greater, the resistance of both alloys in these tempers is not equal to that of material in the artificially aged tempers.)

Since many parts will be heat treated or reheat treated by customers, the influence of quenching water temperature and artificial aging treatments on resistance to corrosion and stress-corrosion cracking of 2219-T 62 is of primary importance. Extensive testing has shown that 2219-T 62 sheet is somewhat less resistant to general corrosion than 2219-T 81 sheet, although both tempers are equally resistant to stress-corrosion cracking. An increase in quenching water temperature from 70 to 150° F. does not appreciably influence corrosion behavior of 2219-T 62 sheet, but it does lower the tensile and yield strength by 2000 psi. Deviations from recommended aging practice for the T 62 temper, however, may lower resistance to corrosion and to stress-corrosion cracking. This is particularly true for material quenched in water at 150° F. versus 70° F.

Samples of ¼ to ½-in. thick 2219 plate in the T 62, T 81 and T 87 tempers show excellent resistance to stress-corrosion cracking (3.5% NaCl, alternate immersion). No stress-corrosion cracking of longitudinal or long transverse specimens was encountered under sustained tension stresses of 75% of the yield strength. Specimens of 2219-T 81 also were resistant to stress-corrosion cracking at the same stress

*J. A. Nock, Jr., is chief, Fabricating Metallurgy Div., Marshall Holt is chief, Mechanical Testing Div., and D. O. Sprowls is research engineer, Chemical Metallurgy Div., Alcoa Research Laboratories, New Kensington, Pa. The general characteristics of alloy 2219 are described here; Part II, "A Weldable High-Strength Aluminum Alloy", to be published in November, will discuss welding characteristics and properties of weldments.

†Nominal percentages of alloying elements present are 6.1% Cu, 0.3% Mn, 0.15% Zr, 0.1% V and 0.06% Ti.

Table I – Corrosion Resistance of Commercially Heat Treated Sheet of 2219, 2024 and 2014

Alloy and Temper	Type of Attack (a)	Loss in Tensile Strength (b), %				Stress-Corrosion Cracking (e)			
		48 Hr. A.I., NaCl–H_2O_2		12 Wk. A.I., 3.5% NaCl		12 Wk. A.I., 3.5% NaCl		1 Yr., Sea Coast Atmosphere	
		Not Stressed	Stressed 75% of Y.S. (c)	Not Stressed	Stressed 75% of Y.S. (d)	F/N	Days to Fail	F/N	Days to Fail
2219-0	P + I	8	—	14	—	—	—	—	—
T 31	I	16	23	25	34	2/2	7, 12	2/2	82, 82
T 37	I	18	30	32	43	2/2	5, 7	2/2	82, 82
T 62	I	14	17	25	38	0/2	OK 84	0/2	OK 365
T 81	P	11	14	17	24	0/2	OK 84	0/2	OK 365
T 87	P	11	14	14	26	0/2	OK 84	0/2	OK 365
2024-T 3	P + I	13	18	23	27	9/14	6-33	4/13	35-77
T 6	I	19	28	29	31	3/4	6, 7, 20	—	—
T 81	I + P	17	19	24	22	0/7	OK 84	0/12	OK 365
2014-T 6	P + I	18	24	30	39	3/6	9, 16, 21	0/6	OK 365

(a) P = pitting; I = intergranular; S = slight. (MIL-H-6088B).
(b) Exposed as cross-grain machined tension specimens, 0.064 in. thick. A.I. = alternate immersion.
(c) Stressed as simple beams with dead-weight loading.
(d) Stressed by bending in constant-deflection fixtures.
(e) Plastically deformed tension specimen blanks, 0.064 in. thick, stressed by bending in constant-deflection fixtures. F/N denotes ratio of number of failures to number exposed.

level, even in the critical short transverse direction. The artificially aged tempers of 2219 plate show a high resistance to exfoliation, comparable to that of 2014-T 6 and 2024-T 81 plate in 3.5% NaCl (intermittent spray) and Miami tidewater exposure tests. Severe exfoliation of 2024-T 3 plate occurs during exposure under these conditions.

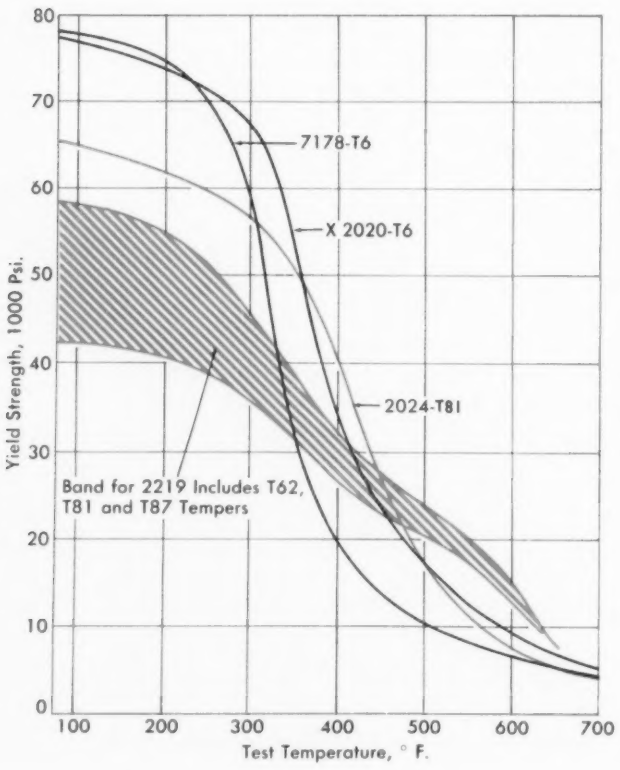


Fig. 1 – Effect of Temperature on Yield Strength of 2219, 2024, 7178 and X2020

Forgings and Extrusions – Stress-corrosion characteristics of 2219-T 6 and T 852 hand forgings are compared in Fig. 2 with those of 2014-T 6 and 7075-T 6 forgings. The data from alternate immersion exposure tests in a 3.5% NaCl solution indicate that 2219 forgings are superior to the other alloys. No stress-corrosion failures occurred under the highest levels of applied stress. Failure of 2014-T 6 and 7075-T 6 forgings occurred at low stress levels when tested in the short transverse direction. Exposure tests of 2219-T 62 and T 81 extrusions indicate high resistance to exfoliation and stress-corrosion cracking.

Susceptibility to Intergranular Attack

Artificially aged products of 2219 are similar to most heat treated and artificially aged aluminum alloys in that some susceptibility to intergranular attack is revealed by the NaCl-H_2O_2 test (see Table I) required by Specification MIL-H-6088B for the heat treatment of aluminum alloys. This tendency does not indicate susceptibility to stress-corrosion cracking or to exfoliation (for properly aged material).

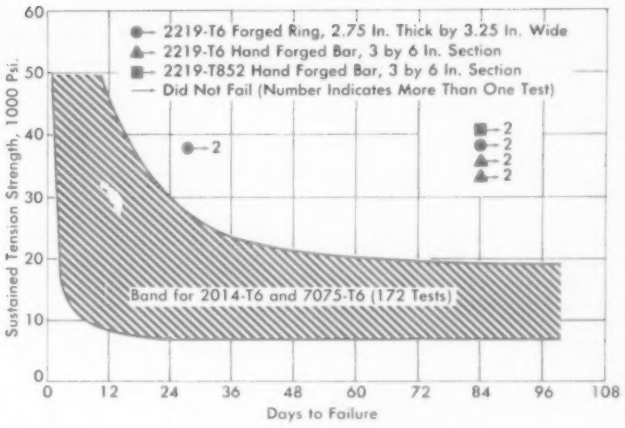


Fig. 2 – Relative Resistance of 2219, 2014 and 7075 Forgings to Stress-Corrosion Cracking. Tests were made on 0.125-in. or 0.437-in. diameter tensile bars after alternate immersion in 3.5% NaCl solution

Intergranular attack in 2219-T 81, T 87 or T 62 (Fig. 3, left) is readily distinguished from that found in insufficiently aged 2219-T 62 (Fig. 3, right), or in some instances in 2219-T 31 or T 37 and 2024-T 3 or T 4. Although the latter type of intergranular attack indicates susceptibility to stress-corrosion cracking under conditions of sustained high tensile stresses, the fact remains that established alloys such as 2024-T 3, T 36 and T 4 have been used successfully for many years.

The recommended artificially aged tempers of both 2219 and 2024 alloys provide assurance against stress-corrosion cracking and exfoliation. Other aging treatments for 2219 may develop slightly higher mechanical properties with some reduction in resistance to intergranular corrosion and to stress-corrosion cracking. Consequently, the user must be prepared to accept the lower resistance to corrosion resulting from such treatments.

Thermal Treatment Develops High Strength

Thermal treatment of 2219 follows the general pattern used for other high-strength aluminum alloys: Solution heat treat at 1000° F., quench in cold water, and age artificially. The latter treatment develops the high strength which makes the alloy attractive to the structural designer. Since the alloy ages very slowly at room temperature, solution-treated and naturally aged material retains good formability for a considerable period of time. In comparison, alloys 2014 and 2024 age rapidly enough at room temperature to develop very useful properties within four days. Maximum formability in combination with lowest strength is, of course, found in annealed 2219 material.

The wide range of strengths in the several tempers of 2219 results from the unexpected and very favorable reaction to combinations of fabricating techniques, solution heat treatments and artificial aging cycles. The naturally aged tempers provide desirable combinations of strength and formability. Artificial aging, upon completion of a forming operation, leads to much higher strength in the final structure. Table II presents typical mechanical properties for material in the several tempers.

The physical properties of alloy 2219 are as follows: specific gravity, 2.83; density, 0.102 lb. per cu.in.; melting range, 1010 to 1190° F.; electrical conductivity (% I.A.C.S.) at 20° C., 44 (annealed) and 32 (T 6). Thermal conductivity in cal. per sq.cm. per cm. per °C. per sec. at 25° C. is 0.40 (annealed) and 0.33 (T 6); and the aver-

Fig. 3 – (Left) Intergranular Attack in 2219-T 62 Sheet Exposed to NaCl-H_2O_2 Solution (MIL-H-6088B). Note the wide and irregular path of attack along the grain boundaries. This material has a high resistance to stress-corrosion cracking. Keller's Etch; 500 ×. (Right) Intergranular Attack in Insufficiently Aged 2219-T 62 Sheet Exposed to NaCl-H_2O_2 Solution (MIL-H-6088B). This material is susceptible to stress-corrosion cracking. Keller's Etch; 500 ×

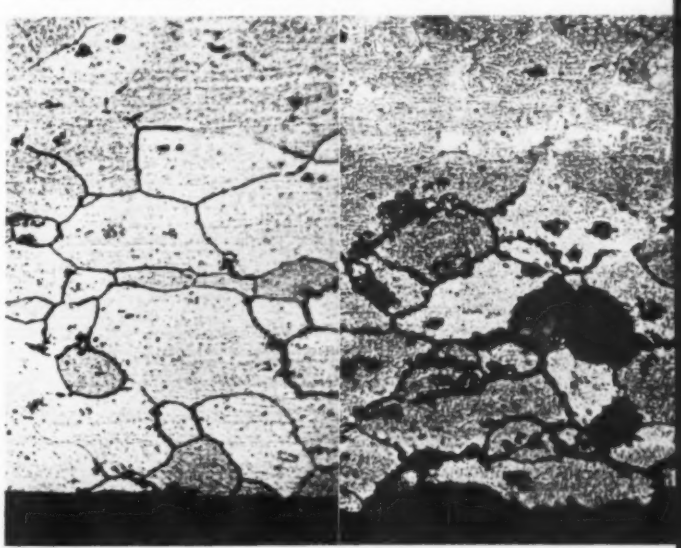


Table II – Typical Mechanical Properties of Alloy 2219 (Not Design Allowables)

Property (*a*)	Sheet and Plate (*b*)							Alclad Sheet
	0	T 42	T 31	T 37	T 62	T 81	T 87	T 62
Tensile ultimate, 1000 psi.	25	53	53	59	60	69	69	58
Tensile yield, 1000 psi.	10	27	39	50	43	54	57	41
Elongation, %	20	20	20	12	11	11	10	10
Compressive yield, 1000 psi.	—	—	35	49	43	56	59	41
Shear ultimate, 1000 psi.	—	—	33	37	37	41	41	36
Brinell hardness	—	—	100	117	115	130	130	—
Bearing strength E/D = 1.5 (*c*)								
Ulitmate, 1000 psi.	—	—	85	88	90	100	100	87
Yield, 1000 psi.	—	—	56	69	67	80	80	64
Bearing strength E/D = 2.0								
Ultimate, 1000 psi.	—	—	111	118	120	131	131	114
Yield, 1000 psi.	—	—	63	78	80	90	91	77
Modulus of elasticity, $\times 10^3$ psi. (*d*)	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.1 (*e*)

(*a*) Tensile and compression data are from longitudinal specimens. Transverse data are similar and slightly lower in most cases.

(*b*) 0 = annealed; T 42 = solution heat treated (S.H.T.) by customer; T 31 = S.H.T. and cold worked a specific amount; T 37 = S.H.T. and cold worked higher amount than T 31; T 62 = T 42 material aged by customer; T 81 = aged T 31 material; T 87 = aged T 37 material.

(*c*) E/D = edge distance/diameter of pin.

(*d*) Average of tensile and compressive moduli.

(*e*) Secondary modulus.

age coefficient of thermal expansion from 68 to 572° F. is 13.6 micro-in. per in. per °F. for annealed material.

At low temperatures, 2219 follows the general pattern typical of all aluminum alloys. Tensile strength of 2219-T 62 sheet increases from 57,000 psi. at room temperature to 91,000 psi. at −423° F. Yield strength increases from 38,000 to 52,000 psi. This strength increase in the cryogenic range is accompanied by a small increase in elongation (from 12% to 16%).

Properties At Elevated Temperature

Since 2219 was initially developed for forged parts to be used up to 600° F., the highest strengths at 600° F. are naturally found in forgings, treated to the T 6 condition. At temperatures up to 400° F., sheet and plate in the T 81 and T 87 tempers develop slightly higher tensile strengths than sheet and plate in the T 62 temper or forgings in the T 6 condition. On the basis of yield strength, a slight advantage for the T 81 and T 87 tempers persists to about 550° F. The effect of elevated temperatures on yield strength (for several tempers of 2219) is indicated in Table III. Figure 1 compares the yield strengths of 2219 at elevated temperature with other high-strength aluminum alloys. The advantage in strength for 2219 at 500 to 600° F. is clearly indicated.

The effect of high-temperature exposure (400° F. or higher) on room-temperature properties of 2219 is to lower the strengths. For example, a ½-hr. exposure at 600° F. lowers tensile strength of 2219-T 62 from 61,000 to 52,000 psi.; a 10,000-hr. exposure lowers it to 31,000 psi. Long exposure (10,000 hr.) at 300° F. will also slightly reduce the strengths of various tempers of 2219 alloy.

Creep and stress-rupture data for 2219-T 6 forged rod are given in Table IV and flexural fatigue strengths at room and elevated temperature are presented in Fig. 4. The endurance limit (fatigue strength at 5×10^8 cycles) is 1000 psi. less than that of 2014-T 6 and 5000 psi. less than that of 7075-T 6. The effects of a severe notch can be noted by comparing the strengths of smooth and notched specimens. At room

Table III – Typical Yield Strength at Elevated Temperatures

Temper	Yield Strength, 1000 Psi.*							
	Room	300° F.		500° F.		600° F.		700° F.	
		½ Hr.†	1000 Hr.	½ Hr.	1000 Hr.	½ Hr.	1000 Hr.	½ Hr.	1000 Hr.
T 62	42	36	32	21	20	16	13	9	4
T 81	53	45	43	24	23	18	12	9	4
T 87	58	47	42	24	23	16	7.5	6	3
T 6	45	39	37	22	22	16	14	10	4.5

*Transverse to direction of rolling for 2219 sheet and plate. The T 6 temper represents forgings in which test specimens were taken parallel to grain flow.

†Time at temperature.

Table IV – Creep and Stress-Rupture Properties of Forged 2219-T 6 Rod

Temperature	Time	Strength, 1000 Psi.*			
		Rupture	1.0% Creep	0.2% Creep	0.1% Creep
Room	1 hr.	62	59	45	39
	100	59	55	40	37
	1000	58	50	39	36
212° F.	1	51	46	36	33
	100	47	40	32	32
	1000	45	39	32	31
300	1	43	37	31	28
	100	37	33	27	25
	1000	34	32	26	24
400	1	32	28	23	21
	100	25	23	18	16
	1000	23	21	15	13
500	1	23	21	16	13
	100	17	15	10	7.5
	1000	14	12	8	5.5
600	1	15	14	10	8
	100	9	7.5	5	3.5
	1000	6.5	5.5	3	2
700	1	7	6.5	5	3
	100	3.5	3	1.5	1
	1000	2	2	1	0.5

*2219-T 81 and T 87 develop values higher than these for temperatures through 400° F.

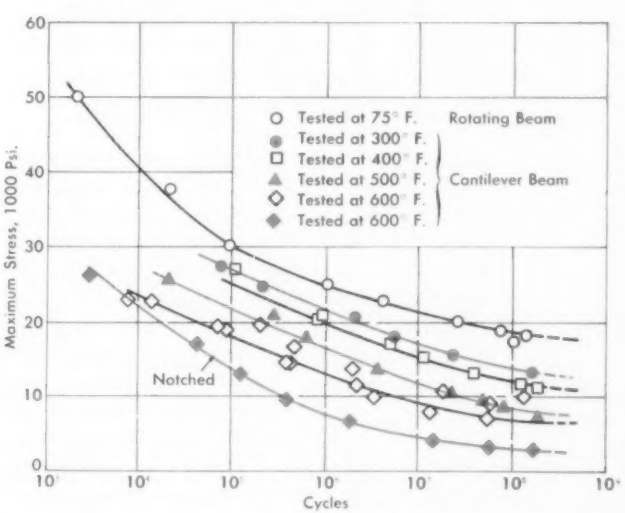
temperature, the strength-reduction effects are somewhat greater than those indicated at 600° F.

Fabricating Characteristics and Formability

Alloy 2219 can be made in practically any wrought product desired – forgings, sheet, plate, rolled rod and bar, extrusions, tubing, alclad sheet and plate, and rivets. Alclad products are made with a 7072 cladding to provide electrochemical protection.

Formability, at a maximum in the annealed temper, is equal to or slightly superior to that of other high-strength aluminum alloys such as 2024 and 7075. As the strength increases in other available tempers, formability decreases. For a forming operation, the condition of tools and of the surface of the material are very important in establishing production limitations. In general, severe forming and drawing operations should be done with annealed stock, and the tools must be clean and free of scratches. Less severe operations may be done on material in the T 42, T 31 and T 37 tempers. Although some mild forming operations can be performed on artificially aged material, the more critical operations should be done while the material is in the solution-treated or naturally aged condition.

Fig. 4 – Effect of Temperature on Flexural Fatigue Strength of 2219-T 6 Forged Bar. All specimens were smooth except as noted



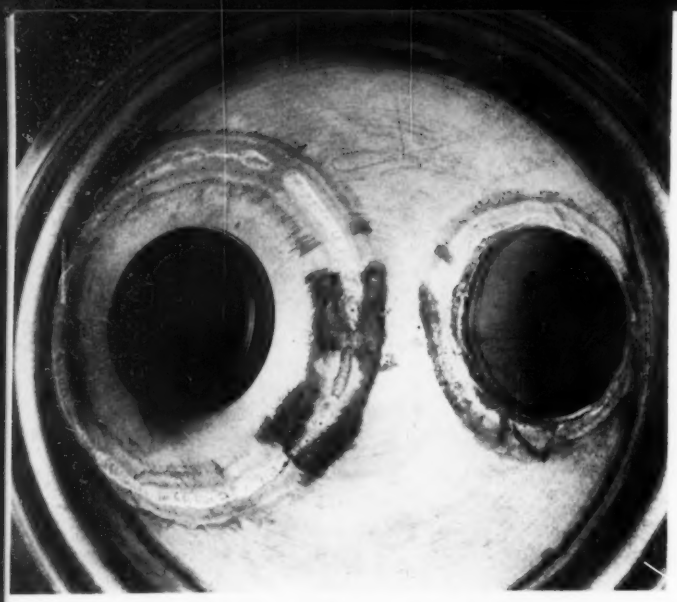


Fig. 1 – Inadvertent Carburization During Hot Spinning Raised the Carbon Content of This Stainless Steel Part to a Level Too High for the Amount of Stabilizing Elements Present in the Alloy. Later, when the part was welded, sensitized areas developed. Corrosion occurred during storage

Why Does Stainless Steel Corrode?

*By MORGAN SINCLAIRE and EUGENE PHILLIPS**

Unexpected corrosion of stainless steel can occur unless certain precautions are taken during fabrication and while parts are in service. Sensitization, carburization, sources of hydrochloric acid and dirt are the main causes of failure. The authors explain why and point out the preventive measures that should be taken. (R-general; SS)

MANY FABRICATORS AND USERS of stainless steel have often discovered, much to their chagrin, that these steels are not always stainless in all kinds of environments but are, instead, merely corrosion resistant. The corrosion which occurs is apparently inexplicable, usually unexpected, and sometimes leads to catastrophic consequences. For successful application of this valuable series of alloys, an understanding of the basic mechanism by which they corrode and resist corrosion is essential. Only then is it possible to specify proper design criteria, fabrication procedures, and maintenance.

Sensitization: the Most Common Problem

Perhaps the most commonly recognized phenomenon is intergranular corrosion resulting from sensitization. Occurring principally in austenitic stainless steels when they are heated in the range 900 to 1400° F., sensitization leads to precipitated chromium carbides at the grain boundaries, chromium depletion in zones adjacent to these grain boundaries and a difference in solution potential between the center of the grains and their outer chromium-depleted zones. It can be minimized by limiting the amount of carbon or by adding a stabilizing element such as titanium, columbium or tantalum. These elements have a higher affinity for carbon than does chromium and their carbides are therefore preferentially precipitated. If parts will be used in the sensitizing range, they must be made from stabilized grades.

But even stabilizing elements do not prevent sensitization under all conditions. For example, in a carburizing environment, the carbon content of the steel may be raised beyond the capability of the stabilizer. Obviously the carburized surface is then subject to the same chromium-carbide precipitation as an unstabilized steel.

It should be recognized that carburization can occur as a result of discrepancies in fabrication as well as service conditions. To avoid it, stainless steels should be kept away from any carburizing atmospheres such as natural gas, carbonaceous furnace atmospheres, or rich oxyacetylene flames. They must be free from all grease and carbonaceous soil before heating. Marking devices such as graphite pencils and wax crayons, which leave a heavy deposit of carbon on the surface, must not be used.

Figure 1 illustrates hemispherical caps that

*Corrosion Engineers, Materials and Process Engineering, Douglas Aircraft Co., Inc., El Segundo, Calif.

were carburized inadvertently during hot spinning by an oxyacetylene flame, used for softening, and by a greased spinning tool. Subsequent welding developed sensitized zones adjacent to the welds. Corrosion occurred during a period of storage.

Entrapped Corrodents

At times, fabricators of stainless steel sow the seeds of corrosion problems by unknowingly entrapping potential corrodents in their assemblies. Generally, the insidious corrosion which occurs results from decomposition of a chlorine-containing material.

The most common of these materials is trichlorethylene, a valuable degreasing agent. Although it is one of the most stable of halogenated hydrocarbons, it slowly liberates hydrochloric acid when contaminated with water. The reaction is catalyzed by iron and its rate increases as temperature rises. Corrosion products seem to accentuate the catalysis and cumulatively accelerate the reaction. Although a "stabilizing" agent is incorporated in degreasing grades of trichlorethylene, it merely reduces potential corrosion problems by reacting with any acid liberated. Obviously, introduction of abnormal amounts of water into the solvent produces more acid than can be neutralized by the stabilizer. Sometimes, the water-trichlorethylene mixture is formed on the condenser pipes of vapor-degreasing equipment during hot, humid weather. More often, it results from dipping parts or assemblies in an aqueous medium either before or after degreasing.

Figure 2 illustrates corrosion of a bellows-type gimbal joint resulting from a water-trichlorethylene mixture trapped in crevices.

Fig. 2 – Corrosion of the Stainless Steel Bellows Shown Here Stems From Hydrochloric Acid Formed by the Reaction of a Degreasing Solvent and Water Trapped in Crevices of the Part. The corrective measure was simple. Parts are now dried at 190° F. after leaving the degreasing tank

The corrosion occurred while the part was stored in a sealed plastic bag, containing VPI (vapor-phase inhibitor) paper. Although analysis of the corrosion product revealed no trace of chloride (it had volatilized), the cause of corrosion was tentatively identified by the characteristic velvety appearance of the rust. This conclusion was confirmed when investigation of the manufacturing sequence revealed that a water-pressure test had been performed immediately after vapor degreasing. The addition of a simple baking operation (30 min. at 190° F.) after degreasing cured the problem.

Other materials to which corrosion problems have been attributed include vinyl chloride plastics, chlorinated lubricants, and plastics catalyzed with hydrochloric acid. Figure 3 illustrates an example. Corrosion of the hot-air duct, a welded part of stainless steel, resulted from decomposition of the phenolic binder in an insulating fiberglas blanket which covers the duct in service. A foil shroud which holds the blanket in place confined the hydrochloric acid liberated by decomposition of the binder at the operating temperatures. Obviously, the shroud and blanket prevented discovery of the corrosion before failure of the duct. Removal of the covering revealed pitting, fissuring and general rusting.

If one carefully controls the processing of a stainless steel part so that its microstructure is faultless and entrapped corrosive agents have been avoided, then its freedom from corrosion

How to Prevent Corrosion in Stainless Steel

- Passivate stainless steel parts.
- Keep surfaces clean.
- Eliminate configurations which trap moisture.
- Remove manufacturing debris, fluxes, and tool and die pickup.
- Remove all traces of chlorinated degreasing solvents.
- Eliminate materials that evolve hydrochloric acid.
- Avoid carburization.
- Keep processing and operating temperatures below 800° F. for unstabilized stainless.

Fig. 3 – Corrosion in This Stainless Steel Hot-Air Duct Was Not Discovered Until Part Failed in Service. The duct was covered by a fiberglas blanket containing a phenolic binder. At the operating temperature, the binder decomposed to form hydrochloric acid which caused rapid pitting, fissuring and rusting

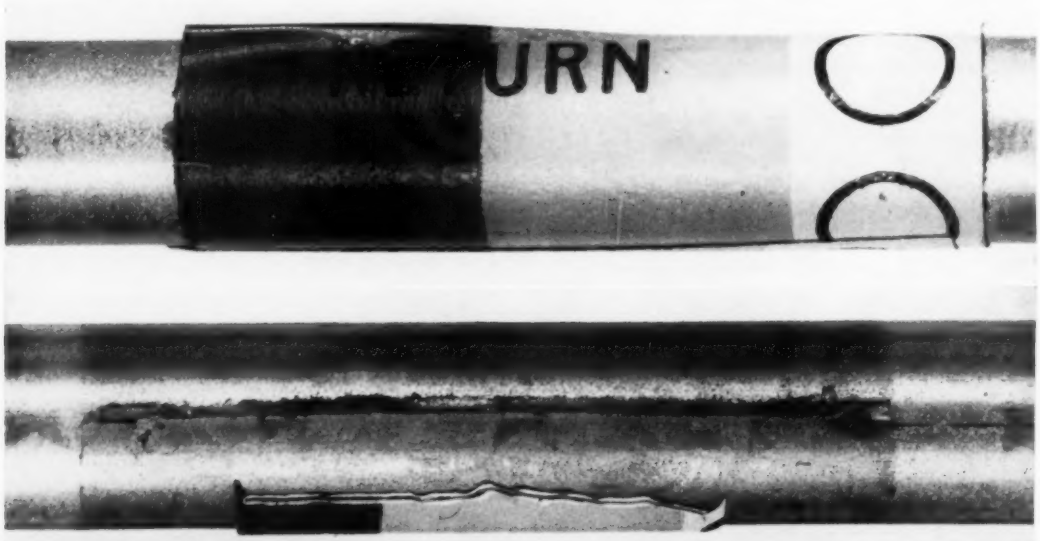
during service will depend on its configuration and environment. The first of these two factors is solely the responsibility of the designer and he must recognize that stainless steels are not a panacea for any and all corrosion problems. To achieve corrosion resistance in all of his stainless parts, he must be cognizant of the mechanisms by which corrosion may be initiated – he must be aware of the weaknesses as well as the advantages of these alloys.

The high resistance to corrosion exhibited by stainless steel is due to its ability to form a thin but tight submicroscopic oxide film on its surface, the so-called "passive film". Without this film, the corrosion resistance of stainless alloys would not be much better than that of ordinary carbon steel. Stainless steel possessing this film is said to be "passive"; lacking this film it is referred to as "active".

The composition and thickness of the oxide film are variable depending on heat treatment, surface preparation and composition of the alloy. Normally, it consists mainly of chromium-oxide with a small quantity of iron oxide and a trace of nickel oxide. The greater the chromium-oxide content of the passive film, the more protection it will afford. Stainless steel will form a passive film on its surface in air or other oxidizing media, such as water which contains dissolved oxygen, and of course in a nitric acid solution, the well-known passivating bath. In a sense, the film actually represents corrosion of the stainless steel but because it is so thin, tightly adherent, insoluble and somewhat impervious to most liquids, gases, and ions, it protects the underlying metal from continued oxidation or corrosion.

As might be expected, the passive film alters the electrochemical behavior, or solution potential, of the underlying metal because it interferes with the flow of ionic traffic to and from the metal. Thus, in a saline solution it acts as a retarding screen to the migration of chloride ions to, and ferrous ions from, the metal surface.

Fig. 4 – Even Improperly Applied Labels Can Cause Corrosion in Stainless Steel Tubing. The wrinkle in the label (top) can trap moisture which will then establish an oxygen-concentration corrosion cell and lead to failure (bottom). The problem is aggravated by high pressures in hydraulic lines commonly used in aircraft (note burst in the failed tubing)



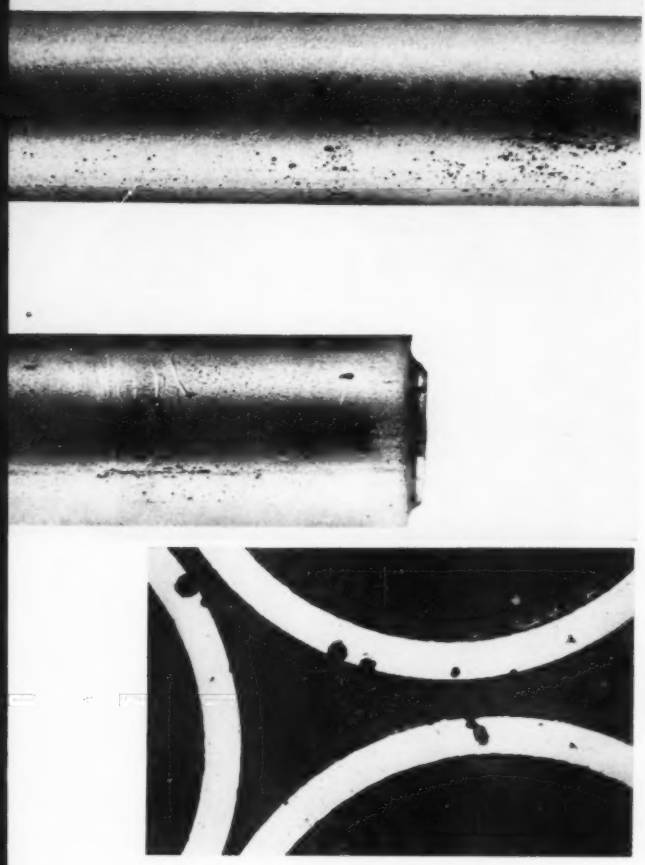


Fig. 5 – Pits in Stainless Tubing Demonstrate Importance of Keeping These Components Clean. Segments of hydraulic lines shown here were taken from carrier-based aircraft. The extensive pitting was first blamed on fatigue but actually resulted from dirt which, in the presence of chloride ions from the marine atmosphere, established corrosion cells. The cells destroyed the oxide film responsible for corrosion resistance of stainless steel. Inset shows cross section of pits

The net effect of this behavior is to make the passivated stainless steel more cathodic or more noble than an active alloy. The difference in potential between passive and active stainless is reported to be between 0.5 and 0.6 v., a significant difference in corrosive activity. If the passive film is interrupted or partly removed, an electrolytic cell will be formed between the active (anodic) and the passive (cathodic) areas when an electrolyte is present; corrosion will occur. It follows, then, that both design and maintenance must be aimed at maintaining the integrity of the passive film.

Crevices and Recesses Are Dangerous

It has been pointed out that the passive film does not form a completely impenetrable barrier; it impedes but does not completely stop the flow of ions and electrons. Thus, corrosion can be initiated through the passive film on the metal beneath. When this occurs, integrity of the passive film in the corroded area is completely destroyed and the area becomes active.

One of the common mechanisms which initiates corrosion of stainless steel is the formation of an oxygen-concentration cell. This results from localized oxygen starvation such as occurs beneath a covered area of a stainless steel surface. Corrosion resulting from this source is referred to as "contact corrosion" or sometimes as "crevice corrosion". Oxygen from the air will dissolve readily in an electrolyte exposed to air; however, an electrolyte trapped between two contacting surfaces is almost completely shut off from a source of oxygen. This area is then forced to become anodic to the surrounding uncovered, high-oxygen area which becomes an oxygen cathode. Corrosion occurs at the anode (covered) area, the corrosion products destroy the passive film, and an active area results. The potential difference between this active area and the surrounding inactive area creates a destructive corrosion cell. It is fairly obvious that folds, seams, or recesses on stainless steel parts will be particularly vulnerable to this type of attack. Similarly, but perhaps not so obviously, crevices formed by washers, tunnels formed by overlapping of labels, improperly applied labels (see Fig. 4) or poultices of encrusted dirt will also create corrosion sites.

Surface Contaminants

Pitting is the usual form of attack experienced by stainless steel in marine and industrial atmospheres. Although the actual quantity of metal lost as a result of pitting is usually slight, it can spoil appearance and in certain instances where pit growth continues to the point of complete, or even near complete perforation, the consequences can be serious.

Shown in Fig. 5 are several failures (pin-hole leaks) in stainless steel hydraulic lines taken from naval aircraft which were based aboard aircraft carriers. Originally blamed on fatigue, the failures were actually caused by corrosion. Metallurgical investigation of the leaking lines revealed no inclusions or abnormalities in the microstructure; the material was free from precipitated carbides and surface imperfections. Chemical analysis indicated no discrepancies and a Huey test showed no susceptibility to intergranular corrosion.

It was found that pitting occurred on top and bottom quadrants of horizontal portions of

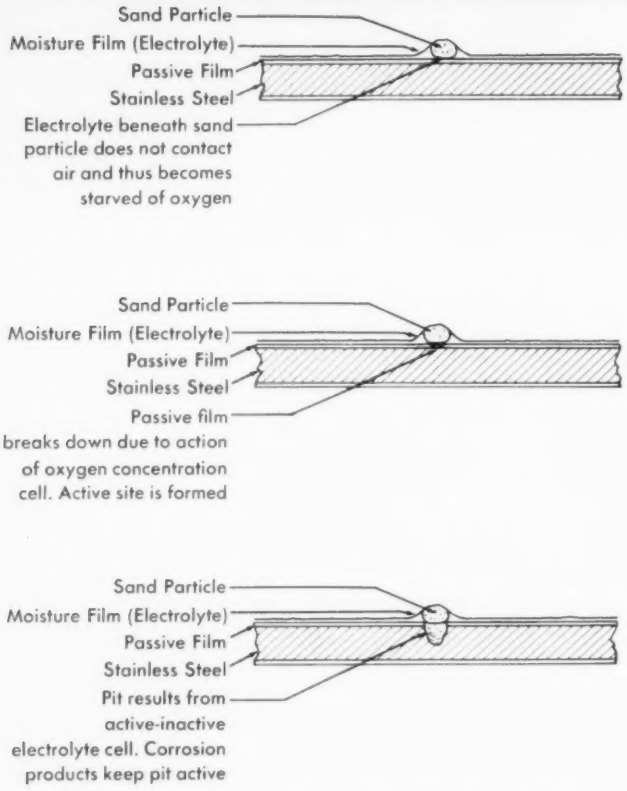

Sand Particle
Moisture Film (Electrolyte)
Passive Film
Stainless Steel
Electrolyte beneath sand particle does not contact air and thus becomes starved of oxygen
Sand Particle
Moisture Film (Electrolyte)
Passive Film
Stainless Steel
Passive film breaks down due to action of oxygen concentration cell. Active site is formed
Sand Particle
Moisture Film (Electrolyte)
Passive Film
Stainless Steel
Pit results from active-inactive electrolyte cell. Corrosion products keep pit active

Fig. 6 — How Particles of Dirt Cause Corrosion of Stainless Steel. The particle excludes oxygen from the electrolyte between it and the stainless steel. Thus, the area under the particle becomes anodic to the surrounding, uncovered area of the steel which is exposed to air. In a marine environment, chloride ions in the pits will maintain a rapid corrosion rate

lines in areas normally open to the atmosphere. These lines were always found to be covered with dirt particles composed mainly of sand, sodium chloride, and iron oxide. Microchemical tests also disclosed the presence of chloride ions within the pits.

The same pitting damage was reproduced in the laboratory on a section of new, sound tubing by sprinkling sand or powdered iron on it and placing it in a humid, saline environment. Both of these contaminants initiated minute active areas which subsequently became pits. As shown in Fig. 6, the mechanism for this kind of corrosion begins with the formation of an oxygen-starved area under a particle of dirt. The corrosion products found in the pit are mainly ferrous and ferric chlorides. These products hydrolyze in water, yielding a significant quantity of hydrogen ions and, of course, chloride ions. Both chloride and hydrogen ions are effective depassivators; they prevent the surface of the pit from repassivating. A typical pit in stainless steel is actually a tiny anode (active site) surrounded by (and electrically coupled to) a relatively enormous cathode (passive area). Because of the high anode current density, pit depth can increase rapidly if enough moisture and chloride ion are present.

Metal Particles Cause Corrosion

Steel or iron dust contaminating a stainless steel surface will create an active site even more readily than sand. Unfortunately, this type of contamination is very common in airborne dust in urban and industrial areas. When an iron or steel particle resting on a stainless steel surface becomes covered by a film of moisture, it rusts rapidly since it is anodic to stainless steel. The corrosion products of the steel particle will depassivate the stainless steel on which they are deposited. This creates an active site and a subsequent pit.

In marine environments, salt crystals can also initiate active sites. They provide a good electrolyte under humid conditions and since the metal beneath the crystal is deprived of oxygen, pitting proceeds by typical contact phenomena.

To avoid corrosion originated by metallic dust, sand and salt, the surface must be kept clean. Soap or detergent will generally remove this type of contamination. Rubbing with a dry cloth is not advisable since it may scratch polished surfaces and damage the passive film. If the particles cannot be removed by washing, indicating that pitting has already started (particles are "glued" to the surface by corrosion products), a nonscratching polishing preparation should be used to restore the integrity of the surface. If regular maintenance is not practical or possible, the surface may be coated with a protective compound or painted if a bright polished finish is not needed.

One of the common sources of premature corrosion of stainless steel is acquired during fabrication in the form of metallic contaminants transferred from a dull cutting tool or embedded into the surface during grinding, tumbling, polishing, sand or shot-blasting and drawing or forming. This type of contamination can usually be removed in a passivating bath and this is one of the important benefits of passivation. Electropolishing of the stainless surface is a very effective means of removing material transferred to it from cutting tools; the smooth finish also helps to increase corrosion resistance. Ammonium citrate or other mild pickling solutions have been used to remove metal pickup, particularly where contamination is heavy.

This sidewalk is wired for snow

Nickel alloy electric heating cables in the concrete melt snow as fast as it falls!

No shoveling, no salting, no customer accidents on slippery sidewalks at *this* suburban branch of a Pittsburgh department store. Electric heating cables keep the sidewalks clear of snow and ice during even the worst winter weather.

Saves maintenance costs. In addition to taking the bother out of blizzards, the system eliminates the cost of conventional sidewalk clearance. And further savings are realized because the heating cables—made of 80% Nickel—require no maintenance.

High Nickel alloy cables were used because of Nickel's superior resistance to corrosion, fatigue and extreme temperatures. These Nickel alloy cables will withstand years of repeated heating and cooling, and seasonal expansion and contraction of the concrete.

Just one example of Nickel's versatility. Electric heating cables—also used to melt snow and ice from roofs and driveways—is another example of how Nickel helps make possible new products and processes, and improves existing ones. In most any application, Nickel's wide range of important properties . . . corrosion resistance, strength, long life and beauty, to name just a few ...offers proven advantages.

If your business is metals, or if you use metals in your business, call on Inco for the latest information about how Nickel and its alloys can help you.

Imbedded near the concrete surface, electric heating cables of 80% Nickel keep the sidewalks clear of snow and ice. Cables made by Edwin L. Wiegand Company, Pittsburgh.

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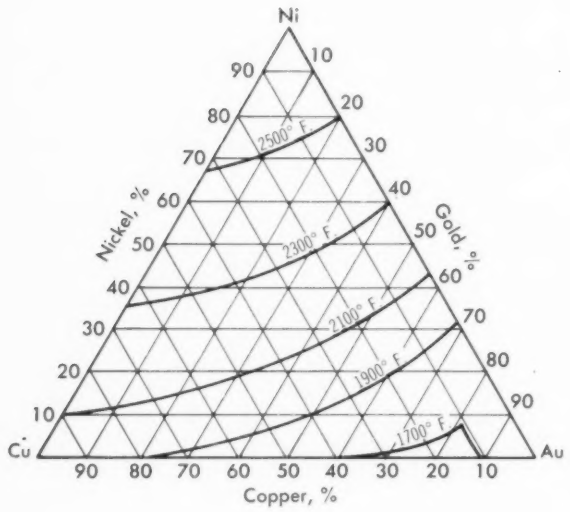
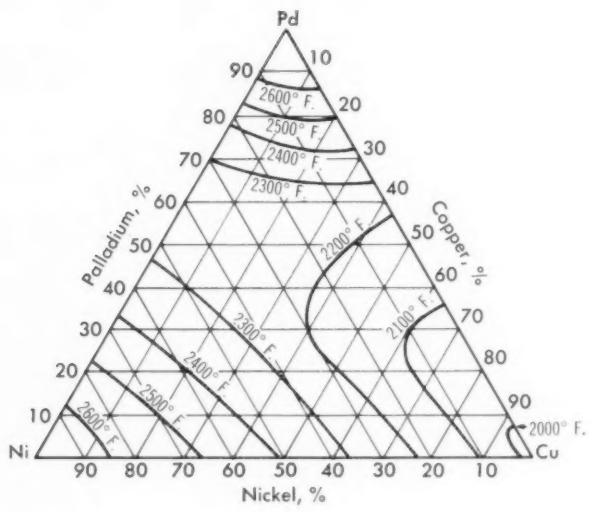
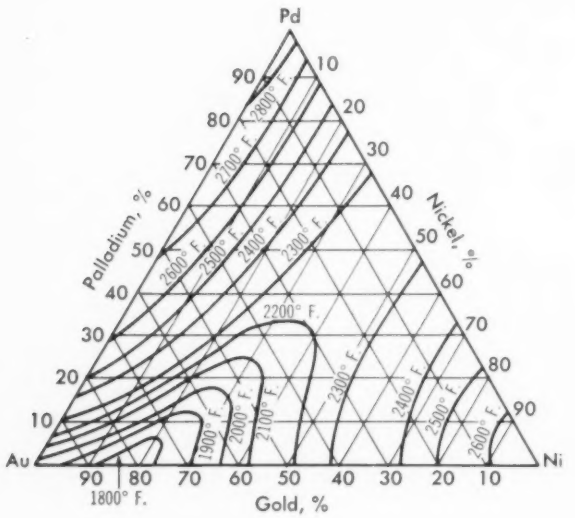
NICKEL MAKES ALLOYS PERFORM BETTER LONGER

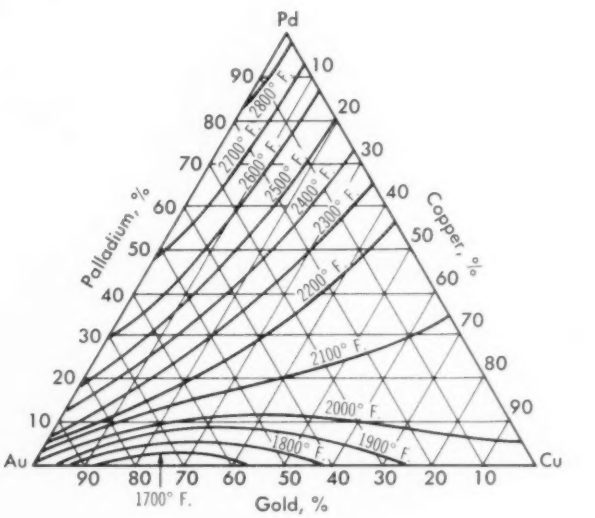
Ternary Systems for Ductile Brazing Alloys

By D. C. Herrschaft
Handy & Harman









These ternary systems have great potential as sources of ductile brazing alloys for elevated-temperature service. Though the data for these nickel-copper-gold, palladium-nickel-copper, palladium-gold-nickel, and palladium-gold-copper diagrams have been extrapolated from limited data from several sources, they should be reasonably accurate for selecting particular compositions for more detailed study.

The Evolution of Ductile High-Temperature Brazing Alloys

*By D. C. HERRSCHAFT**

Silver brazing alloys containing small amounts of lithium, indium and palladium are now being used to bond stainless steel honeycomb, and alloys containing gold or palladium (or both) look promising for jet engine brazing applications. (K8; SGA-F)

BRAZING, AN IMPORTANT JOINING TECHNIQUE today, had its first period of growth early in this century. About 30 years ago, engineers devised a group of low-temperature silver brazing alloys. However, industrial acceptance of these alloys was not widespread until World War II made their employment necessary in many military manufacturing processes. Their advantages were finally recognized, and they have been put to good use on a myriad of consumer items since then.

The advent of jet aircraft and missiles, however, made it obvious that the early silver brazing alloys were no longer adequate to meet many of the special requirements of these advanced designs. During supersonic flight, skin temperature (due to air friction) rises so high that stainless steel in the form of a brazed honeycomb structure, for example, must be used instead of aluminum as the basic material of airframe construction.

Additions Improve Ag-Cu Alloys

Since the common silver brazing alloys were largely based on modifications of the silver-copper binary system (Fig. 1), metallurgists naturally used this system as a starting point to solve the honeycomb brazing problem. Research disclosed that the addition of as little as 0.2% Li to sterling silver (7.5% Cu, remainder Ag) produced a suitable alloy, No. 2 in Table I. It brazed the heat treatable stainless steels (such as 17-7 PH) in inert atmospheres without flux, flowed well, produced good fillets and was not susceptible to interface corrosion. Attesting to its success, this alloy is now used in the production of honeycomb panels for the Convair B-58 supersonic bomber, an aircraft which has recently established new operational military standards for speed and performance.

With the inception of the B-70 bomber program, under the guidance of North American Aviation, Inc., further modifications to the basic "sterling plus lithium" composition were required. Consequently, researchers added minor amounts of indium to reduce the thermal conductivity to a value low enough to allow the honeycomb structures to be used in enclosing fuel storage areas. In a like manner, minor amounts of palladium were added to improve the elevated-temperature strength. Table I lists the resulting composition, Alloy 3.

However, on many honeycomb panel sections, small radii and compound curves made it difficult to establish uniformly sized fillets. (The brazing alloy did its wetting job too well!) A unique solution to this problem was found;

*Assistant Manager, Brazing Products Div., Handy & Harman, New York. The author wishes to acknowledge the helpful assistance of G. S. Sistare, Jr., chief research metallurgist, Handy & Harman, Bridgeport, Conn.

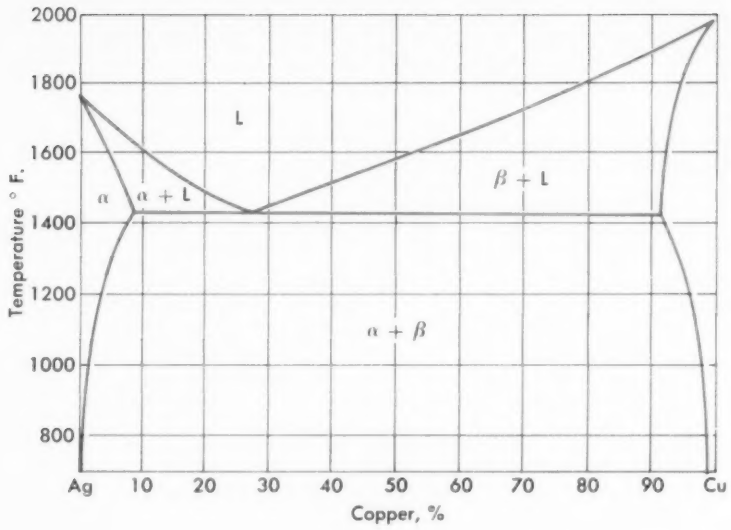


Fig. 1 – Silver-Copper Binary Phase Diagram. Brazing alloys containing these two components plus minor amounts of lithium, indium, and palladium are used in bonding stainless steel honeycomb

about 20 vol.% of dispersed nickel particles was added to Alloy 3. These undissolved particles made the alloy sluggish enough to insure fillet uniformity.

Brazing Alloys for Jet Engines

While the airframe manufacturers have been busy solving the problems of honeycomb construction, jet engine producers have been confronted with even more formidable obstacles in the search for brazing alloys to resist the high operating temperatures encountered in various parts of these engines. Initially, these requirements were met quite well by the use of nickel-base alloys containing two or more of the elements chromium, silicon, and boron in various amounts. (Typical alloys are covered by A.M.S. 4777 and 4778.) However, though brazing alloys of this type exhibit excellent oxidation resistance in the 1500 to 1800° F. range, they are inherently brittle. In addition, those alloys which contain boron are apt to penetrate many of the superalloys to an excessive degree.

As engine designers attempt to increase the operating stress levels at elevated temperatures, the need for ductile brazing alloys becomes mandatory. Why? Under conditions of localized high stress, a brazing alloy that is brittle may

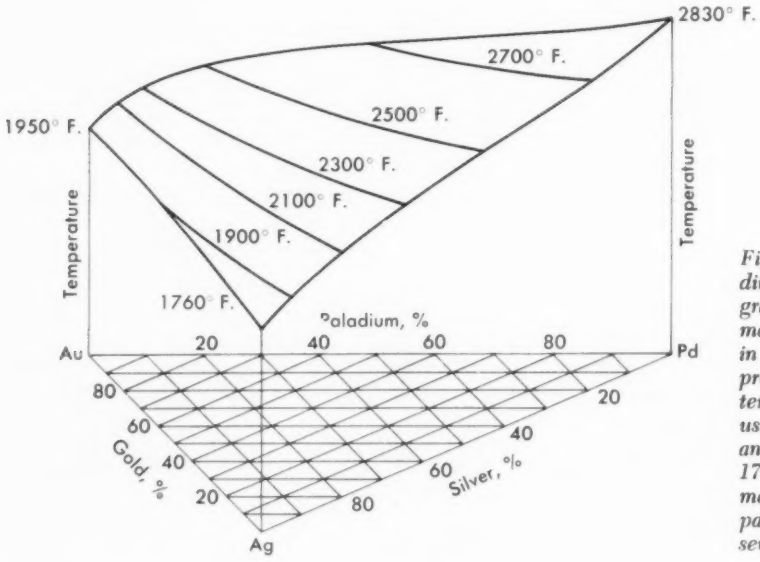


Fig. 2 – Silver-Gold-Palladium Ternary Phase Diagram. Since these three metals are mutually soluble in all combinations, the proper composition in the ternary field will give a usable brazing alloy for any temperature between 1760 and 2830° F., the melting points of silver and palladium. Table 1 lists several such compositions

Table I – Ductile Brazing Alloys for Elevated-Temperature Service

Alloy	Ag	Au	Pd	Cu	Ni	Cr	Other	Solidus	Liquidus
1	71.8%	—	—	28%	—	—	0.2% Li	1400° F.	1400° F.
2	92.5	—	—	7.3	—	—	0.2 Li	1400	1635
3*	84.6	—	2.2%	7.5	—	—	5.5 In, 0.2 Li	1415	1580
4	20	60%	—	20	—	—	—	1535	1555
5	—	80	—	20	—	—	—	1635	1635
6	5	75	—	20	—	—	—	1625	1645
7	—	81.5	—	15.5	3	—	—	1650	1670
8	—	82	—	—	18	—	—	1740	1740
9	—	50	—	50	—	—	—	1740	1785
10	—	75	—	—	25	—	—	1750	1790
11	—	40	—	60	—	—	—	1750	1800
12	80	20	—	—	—	—	—	1780	1810
13	—	37.5	—	62.5	—	—	—	1760	1830
14	—	35	—	65	—	—	—	1780	1840
15	—	32.5	—	67.5	—	—	—	1790	1850
16	—	30	—	70	—	—	—	1800	1870
17	—	35	—	62	3	—	—	1790	1885
18	—	72	—	—	22	6	—	1785	1900
19	8	92	—	—	—	—	—	1930	1945
20	90	—	10	—	—	—	—	1830	1950
21	—	65	—	—	35	—	—	1770	1970
22	75	—	20	—	—	—	5 Mn	1830	2050
23	—	41	27	—	22	10	—	2150	2200
24	—	—	54	—	36	10	—	2250	2300
25	—	87	13	—	—	—	—	2300	2380
26	40	—	60	—	—	—	—	2360	2450
27	—	75	25	—	—	—	—	2490	2550
28	—	60	40	—	—	—	—	2590	2630

*To produce better fillet-forming characteristics, 20% Ni is added to Alloy 3 in the form of dispersed particles.

develop an incipient crack which can propagate rapidly and produce catastrophic failure. However, under similar conditions a ductile brazing alloy will be more likely to yield locally and relieve the stress concentration. Also useful is the ability of ductile materials to absorb kinetic energy under impact loads.

One answer to the need for ductile brazing alloys which can stand high temperatures is met satisfactorily by alloys containing gold or palladium (or both). These metals form ductile alloys of the solid-solution type with numerous other metals that have high melting points. Many of these alloys resist oxidation as well as a variety of corrosive media such as the products of fuel combustion.

Systems With Gold or Palladium Bases

When gold is alloyed with silver, the melting point of the resultant alloy increases almost linearly, with the amount of gold, up to the melting point of gold. Being mutually soluble in all proportions, the two metals form an isomorphous system. The identical situation occurs when palladium is alloyed with silver and (with the exception that the rise in melting temperatures is nonlinear) when palladium is alloyed with gold.

As Fig. 2 shows, the ternary alloy system of palladium, gold and silver exhibits a single-phase structure throughout. Furthermore, all of the Ag-Au-Pd alloy compositions have short plastic ranges and exhibit good flow properties with no tendency toward liquation. Thus, by selecting the proper composition in this system, one can fit any brazing-temperature requirement between the melting point of silver (1760° F.) and that of palladium (2830° F.). The hardest alloys in this system lie in the palladium-rich corner, being above Vickers 90 for some combinations.

Of course, proper melting point and hardness are only two of many criteria on which a brazing alloy is judged. However, binary alloys of silver-palladium and gold-palladium are already being used to braze heat exchangers for aircraft, and high-power vacuum tubes for ground support and search radar systems. In

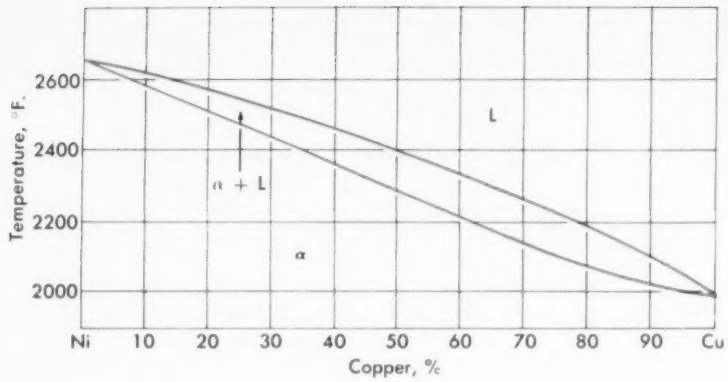


Fig. 3 – Nickel-Copper Binary Phase Diagram. Various combinations of these two elements with gold and palladium are expected to produce good brazing alloys for specific purposes

the latter instance, these alloys have been selected for their low vapor pressure at elevated temperatures.

Other Useful Systems

The nickel-copper system (Fig. 3), a classic example of an isomorphous system, is the basis for the familiar cupronickel alloys widely used in marine piping. It is interesting to note that both gold and palladium form solid-solution systems (binary and ternary) with both copper and nickel. Gold-copper and gold-nickel alloys have been widely used in the vacuum tube industry, and gold-nickel alloys have enjoyed further acceptance for brazing such items as jet engine fuel manifolds and honeycomb seals made of Inconel and stainless steels. The palladium-copper and palladium-nickel alloys have been used for some of the same applications, but to a lesser degree. Both gold-nickel and palladium-nickel alloys can be modified by adding chromium; it helps to improve the oxidation resistance. One alloy of this type (22% Ni, 6% Cr, remainder Au) has been found to be an excellent brazing alloy for René 41 because its brazing temperature of 1950° F. matches the optimum solution temperature for this superalloy. Figure 4 illustrates the oxidation resistance of this alloy.

Other ternary systems which appear to have potential as a source for ductile brazing alloys to be used at high temperatures are shown on the Data Sheet (p. 96-B). They include nickel-gold-copper, nickel-gold-palladium, nickel-palladium-copper, and palladium-copper-gold.

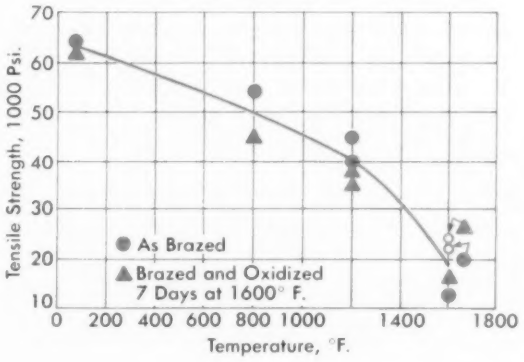
In Conclusion

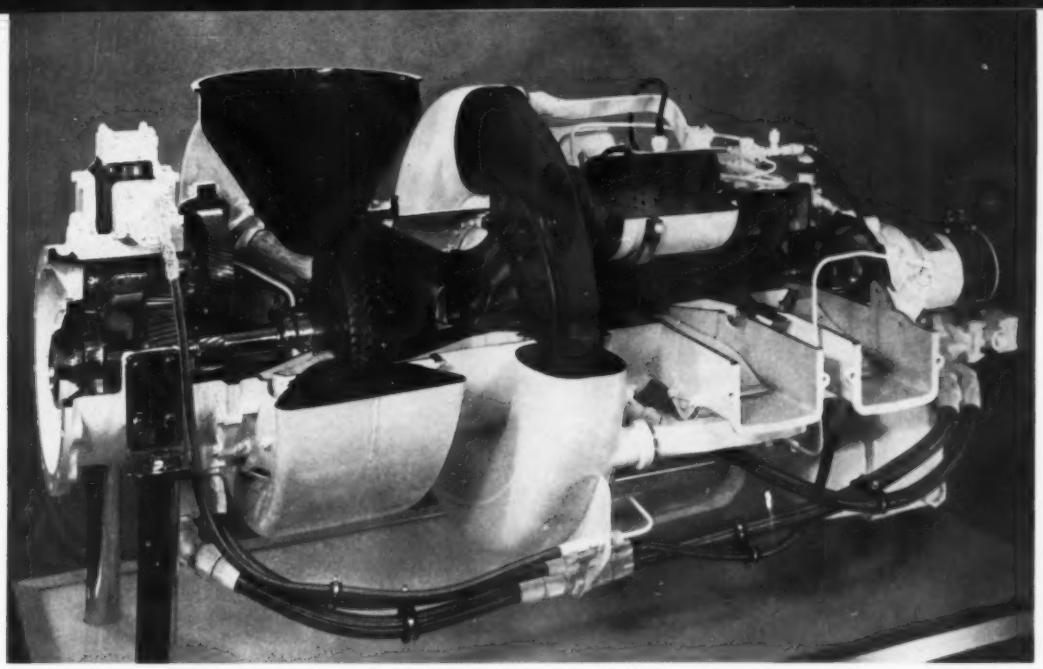
This brief review of some of the alloy systems of precious metals should make it apparent that the means are available to produce vast numbers of ductile brazing alloys which can be potentially useful at high temperatures. Many alloys within these systems are already in use (Table I), but there is room for much more exploratory work.

Of primary concern to the users of these alloys is their high cost. In many instances, however, a critical examination of the application reveals that the expense of the brazing alloy is very small in proportion to the total cost, if the alloy is used prudently. Furthermore, in many items relating to the missile and space programs, operational integrity is the foremost consideration.

Silver-base brazing alloys have come a long way in the last 30 years, and it is reasonable to assume that the next 30 years will see a remarkable growth in applications for brazing alloys containing gold or palladium or both. Looking still further ahead, we may even find platinum being used as a major component in the brazing alloys of the future.

Fig. 4 – Tensile Strength of Joints Brazed with Alloy 18 (72% Au, 22% Ni, 6% Cr) and Tested at Various Temperatures After Oxidation for Seven Days at 1600° F.





Cut-Away View of Boeing 500-Hp. Gas Turbine

Progress in Brazing

Brazing of Components for Small Gas Turbine Engines

*By M. J. STERN**

Brazing is a practical method of producing both simple and complicated assemblies with reproducible quality. Discussed here are techniques and controls employed at Boeing in joining engine components made of René 41 and other high-temperature alloys. (K8; Ni-b, SGA-h)

TODAY, SMALL GAS TURBINE ENGINES of 100 to 500 hp. can be found in heavy trucks, earthmoving tractors, boats, helicopters, and light airplanes. The development of fabrication techniques and materials for these engines presents many unique metallurgical considerations. The small section sizes involved impose severe restrictions on size of flaws and dimensional tolerances; close attention to detail and quality is a necessity.

*Lead Engineer, Welding and Brazing Group, Metallurgical Laboratory, Industrial Products Div., Boeing Co., Seattle, Wash.

Joining High-Temperature Parts

Most formed sheet metal and machined assemblies in early turbine models were joined by manual and automatic welding. Furnace and dip brazing processes now prove more satisfactory because complicated assemblies may be joined with reproducible quality at minimum cost. In addition, component weight

may be reduced and full base-metal strength is retained. The specific advantages of brazing are listed in the box on this page.

Dip brazing is used for aluminum alloy components operating at service temperatures below 300 to 400° F. Furnace brazing is used for low-alloy steels and heat-resistant alloy components operating at temperatures up to 1850° F. Typical hot-section components that are brazed include burner liners, igniters, nozzle boxes, nozzle blade rings, exhaust collectors, and diffuser components (Fig. 1). The diameter of these components is generally under 26 in. and a complicated assembly may contain over 100 brazed details.

Brazing René 41

An interesting furnace brazing technique was used in fabricating the compressor collector-turbine nozzle box assembly shown in Fig. 2. This double-walled unit is about 26 in. in diameter and 15 in. long and consists of a René 41 inner casing, 0.030 in. thick, brazed to a blade-ring subassembly which in turn is brazed to a René 41 outer casing, 0.038 in. thick. The outer casing contains ten tubular extension ports for attaching eight diffuser tubes and two burners. The diffuser and burner port extensions are Hastelloy X and the main front and rear support casings are N-155. The assembly contains a total of 155 brazed details, and requires ten separate brazing operations to complete. All brazing operations are conducted at the same temperature and with the same brazing alloy.

The primary metallurgical problems involved in this project were *(a)* development of suitable interstage annealing treatments to permit forming complicated contours and maintain proper joint clearance; *(b)* development of a suitable brazing process and alloy to withstand multiple brazing plus 1800° F. service temperature; and *(c)* choosing an optimum heat treatment after final assembly to insure adequate strength and ductility in service.

Interstage Annealing – Because of the rapid precipitation-hardening tendency of René 41, satisfactory interstage annealing requires quenching from solution temperature to 1400° F. within 5 sec. Initial annealing attempts with conventional techniques (1975° F. solution temperature; water or fog quench) gave considerable difficulty in forming operations and excessive thinning of the sheet occurred. By placing a large portable quench tank immediately adjacent to the furnace door

Advantages of Brazing

- Permits joining of heat-resistant alloys at or near their solution treating or annealing temperature. This retains full use of material properties.
- Allows flexibility in selection of material, thickness and joint design. A good brazed joint has a higher margin of safety because it provides a larger joint-bond area than is found in welded lap and fillet joints.
- Minimizes fixturing because uniform furnace heating and cooling will produce close-tolerance assemblies consistently. This is very important in the research and development phase where time saved in going from drawing board to engine evaluation is worth a good deal.
- Permits full use of aluminum and titanium-bearing superalloys, such as René 41, 713 C and R-235. Weldability of these sheet materials is unpredictable; even under optimum welding conditions, heat-affected areas are susceptible to strain-age cracking (brittleness) during subsequent stress-relief or during engine operation. Brazing permits close control of processing temperatures and avoids this type of cracking.

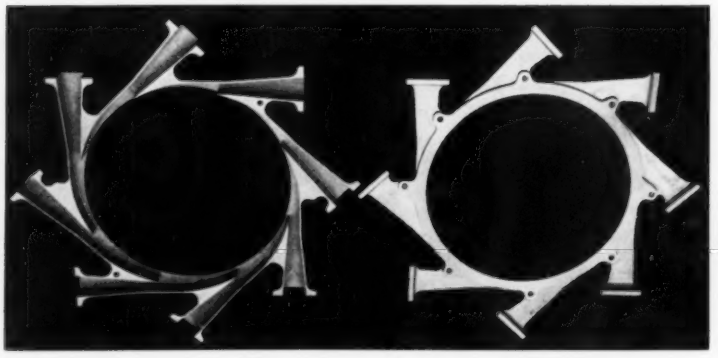


Fig. 1 – Compressor-Diffuser Brazed Assembly. Made of Type 321, it was brazed at 2150° F. with standard Nicrobraz alloy in dry hydrogen

Fig. 2 – René 41 Collector-Nozzle Box Assembly (Double Wall) Brazed in Ten Operations. Braze alloy: Coast Metals 56-GT-W-12 (Table I); furnace temperature: 2060 to 2070°F.; atmosphere: dry argon plus flux activator in a sand-sealed retort

and quenching directly into brine after a 30-min. soak at 2035° F., satisfactory annealing was achieved. Dependent on gage, hardness values ranged between Rockwell A-47 to 57 after this treatment. As-received blanks were also quenched in brine prior to forming.

Some thinning of sheet metal components also resulted from interstage pickling operations. Pickling was eliminated when it was found that an oxide film which formed during annealing did not affect subsequent forming operations adversely.

Brazing Process and Alloy – Since temperatures over 2100° F. will precipitate brittle carbides in René 41 and cause base-metal cracking during subsequent fabrication or in service, a suitable brazing alloy for application at 2100° F. or below had to be found. Tests showed that when parts were brazed at 2150° F. or higher, base-metal ductility could not be restored by final re-solutioning at 1975° F. The strongest alloy evaluated was Coast Metals 56 (A.M.S. 4775), which permitted brazing at 2060 to 2070° F. and showed adequate oxidation resistance. Disadvantages of this alloy are its tendency to erode René 41 excessively and to form rough fillets because of its marginal flowability. Reducing the boron content and acid-washing the powder eliminated these difficulties and satisfactory service has been achieved with the modified alloy, 56-GT-W-12 (Table I). Brazing is accomplished in sand-sealed retorts using a dry argon atmosphere and a flux activator (Nicrobraz Vapo-Flux) in the brazed joint. This eliminates the detrimental reaction of titanium and aluminum constituents often encountered in dry hydrogen and produces stronger joints than those achieved by vacuum brazing. When René 41 sheet metal components are multiple-brazed with this technique, a maximum strength loss of 5% over the as-

Table I – Brazing Alloys Used for Turbine Components

Alloy and Specification	Brazing Temperature*	Nominal Composition, %	Principal Applications
Standard Nicrobraz (A.M.S. 4775)	2150 to 2175° F.	4.5 Si, 0.8 C, 13.5 Cr, 3.5 B, 4.5 Fe, Bal. Ni	General purpose alloy for Hastelloy X, N-155, Type 310 and 321, Incoloy 901. Service to 2000° F.
Low-carbon Nicrobraz (A.M.S. 4776)	2150 to 2175	4.5 Si, 0.15 C max, 13.5 Cr, 3.5 B, 4.5 Fe, Bal. Ni	Low-alloy steel to itself or to a heat-resistant alloy.
Nicrobraz 160	2150 to 2175	2.5 Si, 0.45 C, 10.0 Cr, 2.0 B, 2.5 Fe, Bal. Ni	Wide-gap joints in Hastelloy X, N-155 (up to 0.040-in. gap).
Coast Metals 56-GT-W-12	2060 to 2070	3.7 Si, 0.5 C, 12.7 Cr, 2.8 B, 3.8 Fe, Bal. Ni	René 41, R-235, 713 C. Wide-gap joints in Hastelloy X, Type 347 or 310.
Nicrobraz 170	2175 to 2200	3.2 Si, 0.55 C, 11.5 Cr, 2.5 B, 16.0 W, 3.75 Fe, Bal. Ni	N-155
Haynes 157	2175 to 2200	1.2 Si, 1.2 C, 20.0 Cr, 2.5 B, 4.0 W, Bal. Co	Cobalt-base alloys (L-605) for high strength above 1600° F.
Coast Metals 52 Special	2150 to 2175	4.5 Si, 0.15 C max, 20.0 Co, 2.9 B, Bal. Ni	High strength below 1600° F. in Hastelloy X or N-155.

*Dry hydrogen is a satisfactory atmosphere for all alloys. In addition, Coast Metals 56-GT-W-12 can be used with dry argon and a flux activator.

Fig. 3 – Tack-Welded Subassemblies of Type 310 Nozzle Box Prior to Final Assembly. Furnace brazing is accomplished in one operation in dry hydrogen

received heat treated stock can be expected.

Final Heat Treatment – Due to the slow post-braze cooling cycle in the retort, as-brazed René 41 will develop mechanical properties approaching solution heat treated and aged stock. The best compromise of strength and ductility for engine service can be obtained with a final solution heat treatment at 1975° F. for 30 min., followed by air cooling.

Joints and Joint Clearance

Lap, fillet, butt, corner-brazed and T-joints, as well as combinations of welded joints laid over or immediately adjacent to brazed joints, have been used satisfactorily in various turbine engines. A joint clearance of 0.002 in. is ideal for strength and braze flow in both dip and furnace brazing. A 0.002 to 0.006-in. clearance is permitted for flat and butt joints, while circular joints are specified with a 0.002 to 0.010-in. diametral clearance. Gaps of 0.060 in. have been brazed successfully with "wide-gap" brazing alloys such as Coast Metals 56-GT-W-12 and Nicrobraze 160. Shear specimens tested at room and elevated temperatures up to 2000° F. show that a 1t lap joint will generally

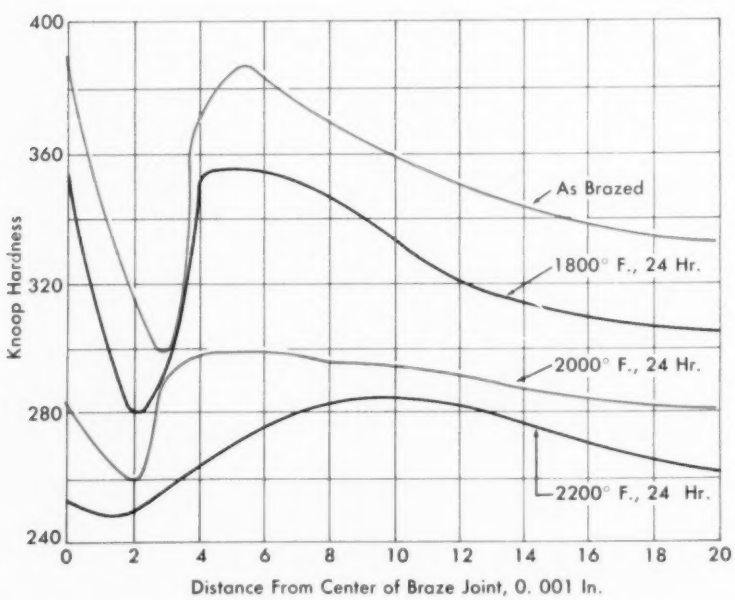


Fig. 4 – Effect of Diffusion on Knoop Microhardness (250 g. Load) for Brazed Joints Shown in Fig. 5

produce failure in the base metal; however, most joints are designed with a 3t to 6t lap. Laps larger than 6t are difficult to alloy for full joint flow, but joint flows of 2.75 in. in 0.060-in. sheet (a 46t lap) have been obtained in telescoped cylinders which were conditioned by steel-grit blasting.

Pre-Braze Assembly – Except on R-235 and René 41 sheet metal components, tack welding with inert-gas tungsten-arc (TIG) equipment after sizing and assembly has been satisfactory for maintaining the position of the part during brazing; thus positioning fixtures are not required. This not only is a cost saving over welding, but it also provides more uniform heating and cooling of the assembly during brazing.

Early in the development of brazing techniques for René 41, it was evident that TIG tack welding could not be used after brazing because of base-metal cracking around the welds. Contoured sheet metal and plate fixtures of René 41, Haynes 25 and Hastelloy X (with pin and wedge hold-downs) were employed; however, this necessitated extra brazing operations. When tack welding is used, complicated components can be alloyed after or during assembly and then brazed in one operation (Fig. 3).

Since maintenance of fitup during brazing is very important, components should be fully annealed prior to pre-braze assembly to relieve internal stresses resulting from fabrication.

Surface Conditioning

Roughing of the faying surfaces of the braze joint is necessary to provide optimum braze flow and bond strength. Where base-metal thickness permits, the best surface preparation is blasting with S.A.E. No. 50 angular steel grit. Components under 0.025 in. thick may distort during blast cleaning and are generally pickled to maintain fitup control. Pickling of freshly machined surfaces of precipitation-hardening alloys, such as René 41 and R-235, will produce a dark, oxidized surface which is resistant to wetting by the braze alloy; however, annealing of these machined parts in air presents no pickling cleanup problems. Coatings for oxidation protection, commonly used in interstage annealing, reduce braze flow and joint strength and are therefore not recommended for parts to be brazed.

Control of Process Variables

For consistent high-quality brazed joints, process variables – alloys, atmospheres, temperatures, cycles – *(Continued on p. 120)*

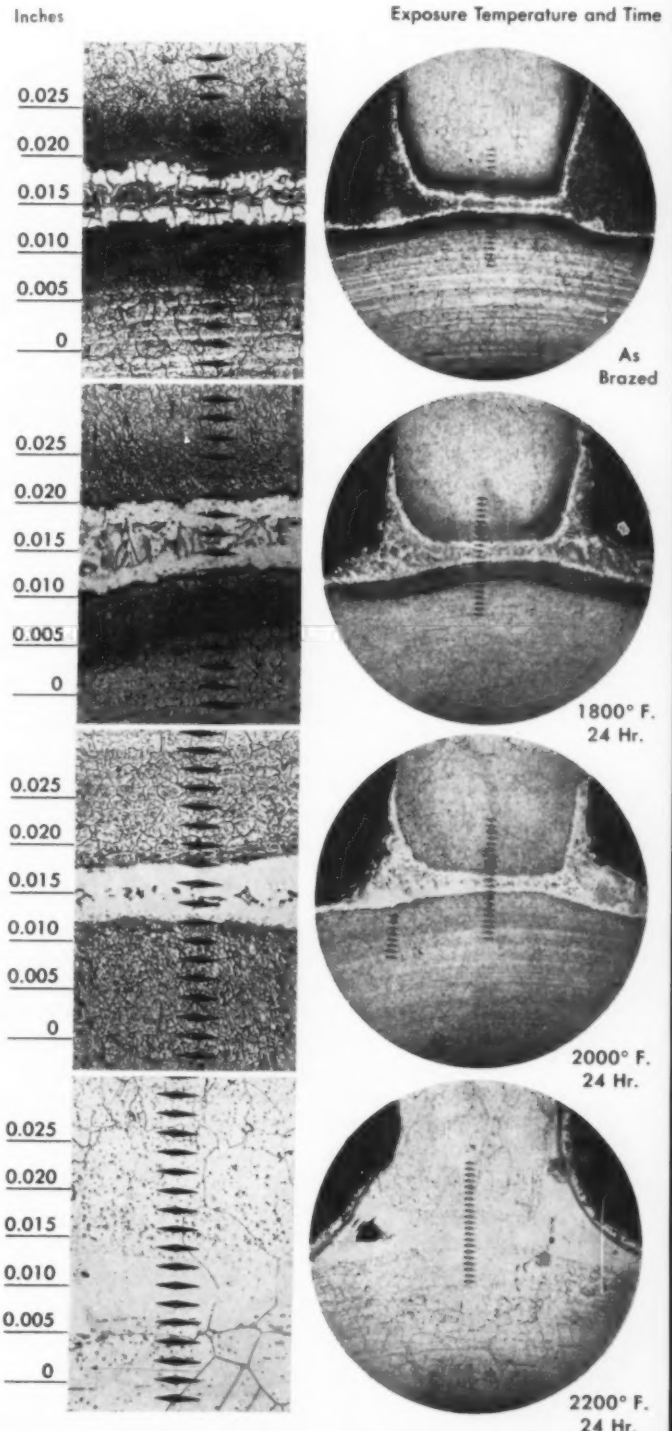


Fig. 5 – Microstructure of Nicrobraz Joints in Hastelloy X After Various Diffusion Treatments in Air Atmosphere. See Fig. 4 for microhardness surveys. 30 × and 100 ×

Progress in Brazing

Calculating Cycles for Brazing

*By H. M. LAMPERT, JR.**

When brazing stainless steel parts, it is necessary to know the times and temperatures at which they should be held during the cycle. This article describes the calculation of a time-temperature parameter, and the subsequent successful use of it in determining optimum cycles for brazing. (K8; SS)

DUE TO THE CONTINUOUSLY more severe operating requirements for advanced missiles and aircraft, the use of nickel-base filler metals for joining assemblies has increased rapidly. The most common of these alloys are the nickel-boron and the nickel-chromium-boron types.

Covered under A.M.S. Specifications 4775A, 4777, and 4778A†, these alloys have similar properties; while brazing, all of them act to dissolve and penetrate stainless steels. Since the alloys are complex mixtures of eutectic phases and intermetallic compounds, joints formed with clearances of 0.004 in. without adequate diffusion and solution are apt to be quite brittle. One cure for this is longer brazing times; this allows more diffusion to occur.

Determining Diffusion Cycles

In evaluating the utility of A.M.S. 4777 for joining structures built of Type 347 stainless steel, it appeared that zero clearances could not be used because, among other factors, the alloy could not flow properly into the joint. Therefore, it seemed necessary to determine diffusion cycles which would assure alloying across a brazed joint which had clearances from 0.002 to 0.005 in. The characteristics of the brazing alloys made it desirable to evaluate their embrittling effects as well as the strengths of the joints.

For these tests, the samples consisted of lap shear joints have an overlap of 4t, the sheet thickness, t, being 0.064 in. (With the exception of the weaker specimens, this test did not provide shear or tensile strength of the braze metal. However, it did indicate the load necessary to fracture the base metal in the assembly.) Samples were prepared (tack welded at their edges to hold a 0.002 to 0.005-in. clearance), and brazed in dry hydrogen (−80° F. dew point), for varying times (15 to 70 min.) and temperatures (1950 to 2050° F.). After grinding off the tack welds, the sheet sections were tested in tension.

During the tests, we found that approximately 15 min. at more than 1900° F. was required for the brazing alloy to melt and flow into the joint. Since diffusion cannot occur before the joint is filled, we did not include the first 15 min. of the time cycle when applying the parameter. This time might be referred to as the "incubation period".

Through use of the generalized parameter,

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†All of these brazing alloys have nickel bases. A.M.S. 4775A contains 4% Si, 16.5% Cr, 4% Fe and 3.8% B; A.M.S. 4777 contains 4% Si, 7% Cr, 3% Fe and 3% B; and A.M.S. 4778A contains 4.5% Si and 2.9% B.

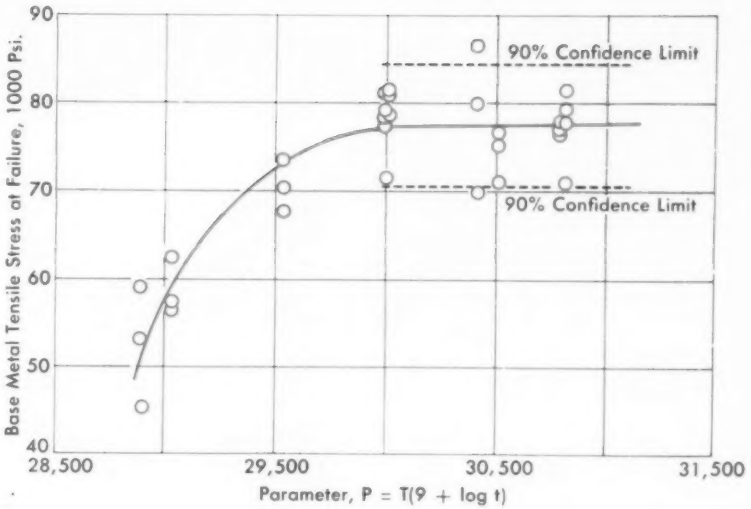


Fig. 1 — Joint Strength in Base Metal Tension as a Function of the Parameter, $P = T\ (C + \log t)$, for Type 347 Stainless Steel Brazed with an A.M.S. 4777 Nickel-Base Brazing Alloy. Above a parameter of 30×10^3 no further benefit is obtained. $T = {}^{o}R; t = seconds$

$P = T(C+\log\ t)$, we evaluated the resulting data. After calculating a constant of nine (when "T" was expressed in degrees Rankine and "t" in seconds), we plotted the data against the calculated parameter value as shown in Fig. 1. (The 90% confidence level is also plotted for all temperatures and times lying above and below the parameter value which resulted in complete solution. Apparently, a parameter of 30×10^3 represents the maximum strength obtainable in a joint having a maximum clearance of 0.005 in. Longer times or higher temperatures are not useful as far as joint strength is concerned.

How the Parameter Was Applied

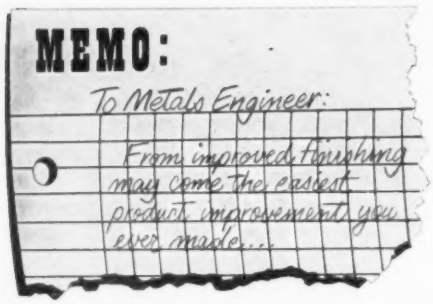
This parameter was then applied to determine the brazing cycle which should be used to develop optimum properties in brazed assemblies. Based on sample testing, brazing temperatures above 1950° F. were impractical in production because of excessive alloy fluidity. Therefore, based on a parameter value of 30×10^3 and a brazing temperature of 1950° F., an effective brazing time of 30 min. is necessary. Plus the "incubation period" of 15 min. mentioned before, this equals a total of 45 min. at 1950° F.

However, further tests indicated that this amount of time at 1950° F. caused excessive flow of alloy. Consequently, a supplementary diffusion cycle at 1850° F. seemed the most practical approach. To supply the equivalent of 30 min. at 1950° F., the time required at 1850° F. is 95 min. (by substituting in the formula and equating).

Since time, temperature, and heating rates cannot economically be controlled with great precision in production, a time of 150 min. at a nominal temperature of 1850° F. was selected. This would allow the temperature in the retort to fall to 1820° F., as a lower limit (again, by calculation from the formula). Therefore, to produce a homogeneous joint over a 0.005-in. clearance when using this brazing alloy with Type 347 stainless steel, heat to 1950° F. or above for 15 min. and hold above 1820° F. for 150 min. Since the upper temperature is a function of the viscosity or flow point of the particular A.M.S. 4777 alloy used, it is only critical insofar as flow is concerned.

Results From Production

Test samples similar to those used to develop this data were included with each assembly joined by brazing. The cycle: Braze 30 min. at 1950° F., cool to 1850° F., and soak 150 min. With one sample from each production run being tested, the average tensile value of the first 33 runs was 77,300 psi., with a 90% confidence limit of ±8000 psi. The scatter, of course, reflects the effect of a number of variables including different joint clearances, different heats of brazing alloy, variations in cleaning and assembling procedures, and heating rates. It therefore appears that this parameter may be used to determine brazing diffusion cycles with some expectation of success. It should be noted, however, that differences in the method of manufacture of A.M.S. 4777 brazing alloys from supplier to supplier makes a great deal of difference in the development of data of this type.



No. 8 in a Series on Better Finishing

How to Get the Most From Phosphating Systems—II

*By GEORGE H. PIMBLEY**

The principles governing spray systems for zinc phosphating are similar to those of dip baths which were discussed last month. One difference is that the reactions must be accelerated to make up for the short processing time. In contrast, manganese phosphating, also described here, can only be done in dip baths because of the large amount of sludge which is always present. (L14b)

ALTHOUGH THE CHEMICAL REACTIONS which take place in spray phosphating systems are the same as those in dip phosphating, the shorter times of contact mean that certain changes in procedure are necessary.

Applications are ordinarily made by spray washers which are large cabinets provided with nozzles, fed by solutions pumped from a reservoir tank. Screens between the reservoir tank and the piping system filter out the larger solid particles so that they will not clog the spray nozzles. Liquids are circulated by pumping the solution from the reservoir tank up through risers and headers, through the nozzles, to impinge upon and flow over the workpieces. The liquid falls onto a sloped floor and drains into a channel that returns it to the reservoir tank.

The reservoirs are provided with heating units such as internal gas tubes, open gas flames, steam pipes, or steam plate units. Large gas heating tubes are the preferred method, with steam plate units as second and steam coils as third choices. Least advantageous are open gas flames.

For zinc phosphating, the pressure and sometimes the arrangement of the spray nozzles for the phosphating stage will differ from those of the other stages. For cleaning and rinsing, vigorous impingement is advantageous, but for zinc phosphating, a solid stream is best. Hence, the phosphating pressure will be 10 to 20 psi., compared to 20 to 30 psi. for the other stages. The phosphating nozzles should be so constructed to produce a flat, solid sheet of solution which bathes every point of the work surface; the stream should not be broken up into a highly aerated mist.

Workpieces are suspended on suitable racks or hooks and moved through the washer by conveyor, passing between the spray nozzles. The speed of the conveyor must be adjusted to

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Fig. 1 – Steel Sash and Frames Being Phosphated in a Unique Spray Washer Prior to Painting. Principles of dip and spray phosphating are the same but in the latter the chemical action of the solution must be accelerated to make up for short treatment time

provide proper contact time in each stage. The pieces must be in position to receive uniform bathing over all of their area, preferably with the largest area in a vertical position. Sometimes it is advantageous to have the hangers on swivels, so that the pieces will spin under the impact of the spray.

Zinc phosphate baths are ordinarily the only heavy-metal phosphates suitable for spray application. (Manganese phosphates are too sluggish in action and make too much sludge to be suitable.) The zinc phosphate spray baths are mostly used on workpieces of large area. Because of the relatively thin, tight coatings produced, the sprayed phosphates are particularly suitable as a base for paint.

Spray Cleaning and Rinsing

As discussed last month, parts must be cleaned thoroughly before being coated; water and inhibitive rinses follow as final stages. These steps require a minimum of five spray washers, but more are needed if the parts are pickled. We must then add the pickling bath, its rinse, an activator and its rinse, thus making a total of nine stages if no other rinses are used. Suitable baffle doors or mobile curtains must be provided between the stages as well as baffle ridges on the floors to prevent contamination.

In spray washers, no cleaning compound or any other product which causes foam can be used in any stage. The preferred cleaner is a reasonably mild alkaline compound (not a heavy-duty type) that will effectively remove soil in the short time, usually 60 sec., but which will not be so harsh as to affect adversely the subsequent phosphate crystal formation. The cleaner should also contain an activator. During operation, spray pressure of the cleaner stage must be sufficient to provide vigorous impingement; 20 to 30 psi. is recommended. The arrangement of spray nozzles must provide a continuous pattern of the cleaner under full pressure at every point of the work surface.

Rinsing in spray washers is, of course, fully as important as in dip phosphating. The temperature of the rinse water after cleaning should be about 130° F. Impingement upon the work surface must be strong enough to remove all cleaner residues; a spray pressure of 20 to 30 psi. is best. After passing through the phosphating stage, parts should be rinsed in cold water for at least 30 sec. The rinse

Fig. 2 – Steel Drums Leave Spray Washer After Being Phosphated at Myers Drum Co., Los Angeles

water should be kept clean by constant overflow and daily change.

For spray systems, the final inhibitive rinse is the same as that used with the dip baths. Time of contact should be about 30 sec. and the temperature at this stage should be from 140 to 170° F. to promote rapid drying. The spray pressure of the water bath and the inhibitive bath should be about 20 to 30 psi.

Make-Up and Break-In

Fresh spray baths for zinc phosphating are made up in the same manner as those for dip baths. Mixing is done by running the spray circulating system. The bath is made up in the reservoir tank which is provided with suitable screens so that none but the very fine particles can get into the nozzles. After being heated to the prescribed operating temperature, the fresh bath must be properly adjusted before it is ready to do satisfactory work.

There are, of course, special considerations to be taken into account for spray baths. For example, contact time is usually not more than 60 sec. Thus, the action of the bath must be accelerated as much as possible, but without damaging the corrosion resistance or any other good quality of the coating. One expedient is to increase the pH of the bath by adding caustic soda at the start. This promotes more rapid precipitation and thicker coatings. Once the phosphating bath is in use, the addition of caustic soda is not necessary because the continuous solution of some metal from the work surface and the accumulation of sodium residue from the nitrite acceleration have the effect of maintaining pH at an advantageous level.

A strong oxidizing accelerator must also be added to get rapid action. The most economic is sodium nitrite. Unfortunately, nitrite cannot be incorporated with the phosphating chemicals and must be added to the bath at the start and continually as the work proceeds.

Zinc phosphate spray baths do not require much breaking in, but, a fresh bath will not produce coatings of optimum quality until at least a trace of iron has become dissolved. Some iron will be readily dissolved from the work surfaces, and if one is content to tolerate somewhat deficient work for the first few work loads, then no further break-in is necessary. It is preferable, however, to introduce a little iron in some form at the start before running through the work loads. Preferably this may be done by adding 2 to 3 oz. per 100 gal. of ferrous phosphate powder.

With the nitrite in and some form of iron introduced, and the spray going, the bath will soon acquire a slightly milky appearance. This is ordinarily an indication that the bath is ready

Operation of Spray Systems

In spray systems for zinc phosphating, time and space intervals between stages and between the final rinse and drying oven must be kept as brief as possible. Care must be taken to avoid delays; the work loads must move steadily, at a rate which will allow at least 60 sec. in each cleaning stage and in the phosphating stage. Rinsing may be done in about 30 sec.

Loading of work should be stopped before idle periods to allow the line to clear before shut-down. Workpieces that are stopped in process will dry and become blotchy, causing unsightly appearance and poor corrosion resistance. Pump pressure must be maintained steadily with the nozzles open and free-flowing

at all times so that every point of the surface will be bathed with a uniform, steady flow of liquid. A filter or settling tank to remove sludge will prove beneficial in the phosphating stage.

In large installations it is particularly advantageous to have all of the chemicals added to the bath in solution form, and to introduce them by means of proportionating pumps. In the absence of such pumps, it is sometimes possible to improvise small reservoir receptacles above the tank with a small hole (or spigot) in the bottom of each which will allow the chemical to run in continuously in a tiny stream. It is necessary, however, to watch the apparatus closely to make sure that none of the orifices become plugged.

Testing and Maintenance

Typical work loads for spray phosphating consist of large pieces. This means that a relatively large surface area passes through the equipment within a short time and, consequently, changes in the state of the bath may occur rapidly. Deterioration in quality may not be observed until after a considerable quantity of work has gone through. Thus, it is necessary in large spray phosphating installations to maintain constant vigilance, with frequent testing and adjustments as required.

The type of coating desired for this kind of work will be relatively thin, tight, smooth, uniform, and with maximum corrosion resistance. Loose smut or powder, blotchiness, coarseness, or poor adhesion cannot be tolerated. This calls for a zinc phosphate solution that is in good balance with very low iron content (not over 0.04 to 0.10%) of adequate strength, and free from excessive sludge or contaminants. The nitrite or other accelerator must be present in correct proportion. Frequent tests are necessary for strength, ratio of "free" to "total" acid* and nitrite content. Tests for ferrous iron are usually not necessary, but should be made if an excess is suspected, with due regard to the mutual interference between nitrite and ferrous iron in the test. The rate of nitrite addition must be watched closely and checked frequently by the nitrite test. Insufficient nitrite will impair the speed and thickness of coating and will allow the bath to acquire dissolved ferrous iron at a rate which may diminish the corrosion resistance. Too much nitrite will make the coatings excessively thin; it gives them a bluish color, indicating that an oxide rather than a phosphate coating is being formed. Either extreme is bad.

Optimum nitrite content in a spray phosphating bath will vary according to temperature and nature of the chemicals employed. It is checked by titration with a standard potassium permanganate solution. When a 100-ml. sample and 0.1 normal permanganate are used, the optimum sodium nitrite content for a conventional bath operating on steel at 130 to 160° F. is represented by 3 to 5 ml. of the standard solution.

Modifications of Spray Systems

One modification of the spray process is the "fixed station" installation, in which the work remains stationary and receives successive sprayings with the various solutions of the process. It appears that this method is adaptable only to fairly large workpieces, and when pickling is not necessary. Otherwise, the general principles remain the same.

Another variation is the low-pressure spray system, sometimes referred to as "Flo-Coat". In these systems, the spraying pressure is about 5 psi. and the time of contact is somewhat longer than with a high-pressure spray. Low pressure in the first stage would probably not be suitable where any obstinate grease is involved. The method is particularly applicable for flimsy, light-weight parts that may be knocked off hangers at high pressure.

Manganese Phosphate Dip Baths

In contrast to zinc phosphate coatings, those of manganese phosphate are relatively thick and porous. They are applied as a base for oils and lubricants, for rust-proofing and antifrictional purposes. The coatings are about 1000 to 3000 mg. per sq.ft. and may be of somewhat coarser, more open texture than zinc phosphates. However, they *(Continued on p. 128)*

*"Free" phosphoric acid content is expressed as the number of milliliters of tenth-normal sodium hydroxide solution required to titrate a 10-ml. sample of the bath to methyl-orange end point; "total acid" is expressed as the total number of milliliters of tenth-normal sodium hydroxide required to titrate the sample to phenolphthalein end point. The "total acid" expression includes the "free acid". The ratio between the two expressions affords a very useful indication of "state of balance" and probable performance such as thickness, adhesion of coating and degree of corrosion resistance. Optimum ratio of the constituents will vary according to type of formulation and the temperature.

Short Runs

"Hot Box" Protects Parts During Welding

By JOHN W. HOLZWARTH*

THE CHALLENGE OF REDUCING WEIGHT, SO prevalent today, has brought about a new set of manufacturing processes and procedures. One of these is the technique required for welding H11 steel. Satisfactory results are obtained when the components to be welded are post heated and maintained at 600° F. during welding operations, when inert-gas metal-arc welding is employed, and when the part is stress relieved in an inert-gas atmosphere at 1200° F. immediately after welding.

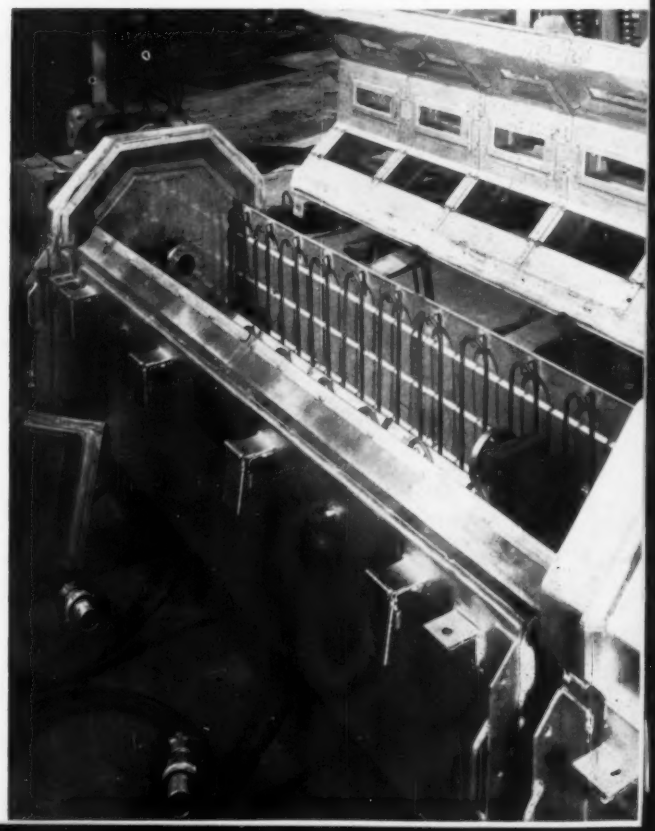
Special equipment in which H11 can be manually welded has been built for North American Aviation, Inc., by Turnkey Engineering Co., Inc., South Gate, Calif. The equipment will accommodate welding fixtures and weldments up to 30 ft. in length. Work can be rotated at any position along the chamber, and access to it is possible through any of 40 removable plug-type access doors. Temperatures of 600° F. (±25° F.) for welding, and 1200° F. (±50° F.) for stress relieving are controlled at 16 heat zones. A protective atmosphere flows into the chamber through a hollow drive shaft of the positioning motor. The entire installation can also be moved.

Basic units of the "hot box" are modular chambers (Fig. 1), each 8 ft. in length and equipped with its own controls and facilities. These sections can be used separately or in combination with the others and, thus, they can accommodate welding fixtures of various sizes. The one thing in common with all the sections is the drive for revolving the welding fixture.

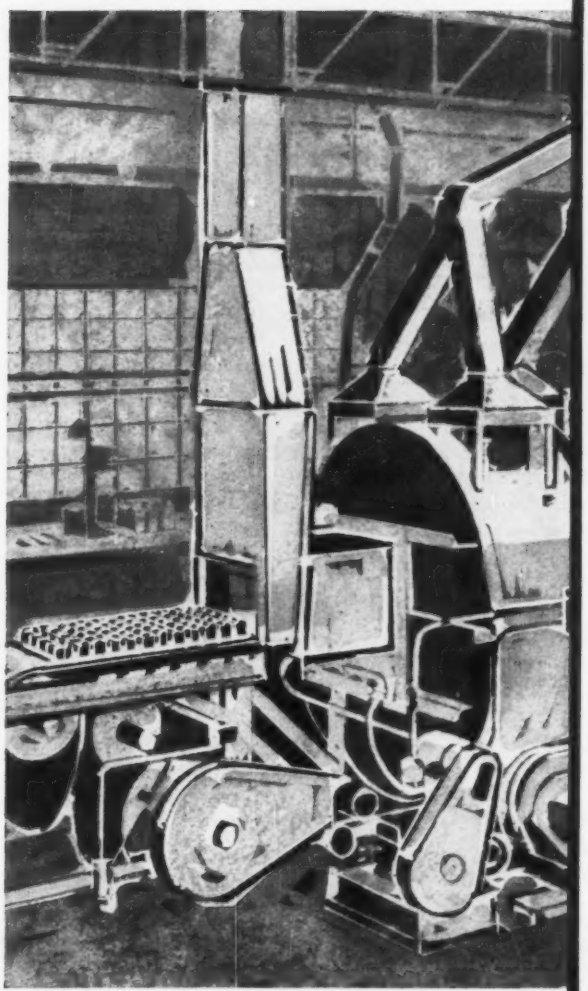
Each chamber consists of an outside shell of ¼-in. steel. Block insulation is sandwiched between the outer shell and a 16-gage stainless steel inner liner. Removable lids are provided for installing the various welding fixtures and for loading them with components to be welded. The lids also contain viewing glasses and five access doors along each of the two adjacent sloping surfaces. Access is gained through two doors where welding is to be performed, leaving all the others in place to keep heat losses at a minimum. Asbestos gloves are worn for protection from heat in the chamber during welding.

An interesting feature of the equipment is the mechanism which revolves the welding fixture. Mounted on the outside at one end of the heated chamber, it consists of a reversible-gear motor driving a hollow *(Con't. on p.128)*

Fig. 1 – Parts of H11 Steel Can Be Welded and Stress Relieved Under an Inert-Gas Atmosphere in This Special Chamber. Motor at opposite end turns a hollow shaft through which the atmosphere is introduced. The flange at the end of the shaft is attached to the welding fixture which holds the components being welded. When the lid is closed, access to the part is gained through small doors



*Vice-President, Furnace Div., Turnkey Engineering Co., Inc., South Gate, Calif.



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This transistorized Potentiometer Controller is available for ranges up to +3000°F. The sensitivity of the controller is 120 microvolts irrespective of span. Time proportioning standard at no extra cost. Available with on-off or 2-positioning. Other features include illuminated dial, flashing lights to indicate when temperature is at "set" point, and an 8" scale for easy setting. Thermocouple burn-out protection inherent in design. Controllers can be surface or flush mounted. Other models with centigrade scales are also available.

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Sales and service offices in all principal cities of the world. Manufacturing in the United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

Circle 1115 on Page 48-B

LETTERS to the EDITOR

CORRESPONDENCE INVITED ON ANY METALLURGICAL SUBJECT • CORRES
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"Tough", Not "Rough"

Readers of "A New Nitriding Process From Germany," an article which appeared in the July 1961 issue of *Metal Progress* (p. 77), may recall that the synopsis preceding the article states that the nitrided case produced on a part "is both file-hard and rough." Actually, this is an unfortunate typographical error on our part; the word "rough" should have been "tough." According to Kolene Co., Detroit, the licensers of this process in this country, one of the advantages is that the surface of a treated part is much as it was before the treatment.

More on Old Razors

WASHINGTON, D.C.

I have a little more information to corroborate and supplement the interesting article, "A Century-Old Razor", by Samuel J. Rosenberg, in the June 1961 issue of *Metal Progress*, p. 94.

If Mr. Rosenberg had received the Kropp razor in its original case, the legend on the case would undoubtedly have read as it does on my cases: "The Kropp Mfg. Co., Sheffield, England".

The Kropp razor was for years made in Sheffield, but ground in Hamburg, Germany, and was a government issue in the British Royal Navy, since it would give a clean shave under nearly any conditions almost indefinitely. It was the only razor that could survive long periods at sea and continued service in the tropics without going bad.

I have been told that enterprising British navvies customarily took along (at one shilling apiece) a half dozen extra Kropp razors when bound for a cruise to the tropics. On shore leave if they spotted a local planter or colonial expatriate with a ragged-looking face, there was seldom any difficulty in exchanging the Kropp for as much as five pounds sterling.

Anybody who has been in a barbershop must have noticed that barbers have and use a plurality of razors. Most straight-razor addicts have sets of seven — one for each day of the week. The reason is that in cool weather (60° F. or lower) most razors will give a fair amount of continuous service (three or four months). But in hot weather (above 80° F.), particularly in hot, humid weather, no straight razor but a Kropp can be expected to shave for more than six continuous weeks. The worst of it is that no amount of stropping or honing will restore a cutting edge to most razors that have given up the ghost in hot, humid weather. The only recourse is to set them aside for a "rest" (the recovery period is one week to six months), whereafter they can again be honed to a cutting edge. By contrast, a Kropp razor resists such failure far longer, and, when dulled, can always be honed with ease under any weather conditions to a sharper edge than other razors.

Of my razors, and the razors used on me in barber shops, the Kropps (Sheffield) are the best; Henry Boker & Co., (Sheffield) second best; German razors third best; American razors fourth best; Swedish razors poorest.

My Kropps are of more recent vintage than the one described by Mr. Rosenberg. One of them (presumably World War I) is marked "Made and ground in Sheffield". By then the British had evidently learned to do as good a grinding job as the Germans. But apparently nobody has learned how to heat treat cutlery steels as well as the British.

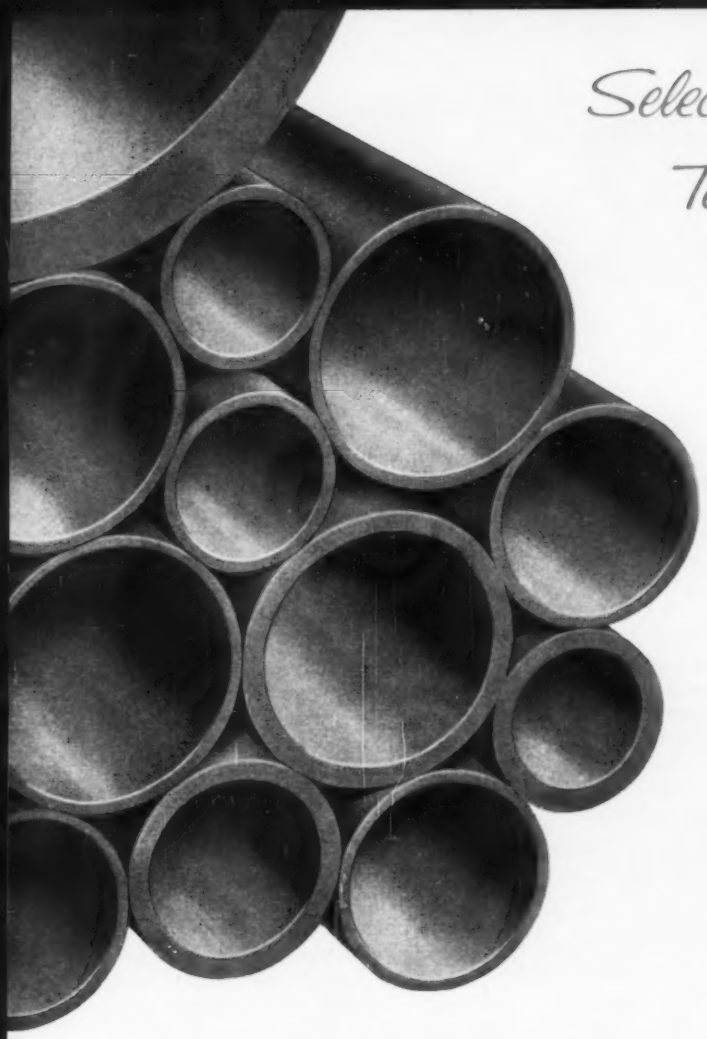
W. J. O'LEARY
Nuclear Power Dept.
Atomic Energy Div.
Allis-Chalmers Mfg. Co.

LOS ANGELES

Since shaving is a way of life to most males, I think the tools are a worthy subject of metallurgical comment.

Mr. Rosenberg reports that his century-old razor was high-grade carbon tool steel. The British, Swedish and Germans all made excellent crucible steel of high purity a century ago. But what is of transcending importance is that the razor was hardened and tempered to Rockwell C-62 — long before the Rockwell hardness tests were invented. This is exactly the correct hardness for razors!

The use of a straight-edge razor reduces shaving to its simplest terms. For this reason, the writer has continued to use one and has acquired some razor lore through activities in



Selection of finest raw materials

Testing every step of the way

Inspection to rigid standards

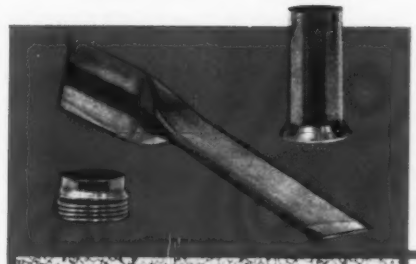
Assure 100% dependability for

OHIO WELDED PRESSURE TUBING

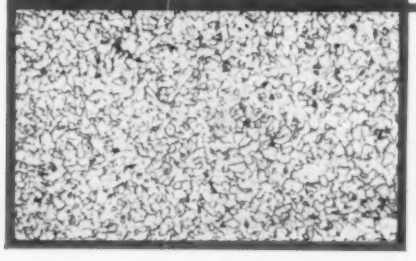
You can be sure — doubly sure — of utmost tubing dependability when you specify Ohio Welded Pressure Tubing — *made by Ohio Seamless.* First, Ohio works to accepted industry standards — ASTM, ASME, and similar Federal and military specifications covering welded pressure tubing. Second, Ohio Welded Pressure Tubing is produced under a *continuous* process of quality control — not just a final test inspection to cull questionable material.

Carefully selected prime raw material is slit, edged, shaped and electric resistance welded on the most versatile and modern equipment in operation. At each and every step of the way Ohio Welded Pressure Tubing is under the scrutiny of Ohio's master tubemakers . . . making control tests at frequent intervals . . . testing random samples from each production order far beyond the limits of the usage involved.

For critical pressure piping applications . . . for condensers, heat exchangers, boilers and superheaters — in the range of sizes from ½ to 7½" OD and wall thicknesses from .028 to .375"— mark your prints "*Ohio Custom Made Welded Pressure Tubing.*" There is no equivalent.



Photographs show flare, flattening and crush tests performed continuously on every order. Non-destructive tests include air, water, magnetic, eddy current and visual inspection to insure 100% dependability.



Photomicrograph of polished and acid-etched surface shows perfect microstructure of normalized Ohio Welded Pressure Tubing. Weld area running down the center is now indistinguishable and tube has become, in every sense, weldless.

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THOMAS', MacRAE'S, CONOVER-MAST, SWEET'S, FRASER'S.

Circle 1116 on Page 48-B

A-4099A

footenotes on the art of producing higher-quality steels

SUBJECT:

hydrogen

Drastic reduction critical to quality steel

Hydrogen is the only common element in steel which is always bad news. Sulfur, phosphorus, nitrogen, silicon, aluminum, lead and even copper have a valid place in some steels. Hydrogen, however, does not alloy in either molten or solid steel; remains gaseous at all times.

Residual Hydrogen Damages Heavy Sections of Steel

While all steels absorb and retain hydrogen, those most sensitive to it are heavy sections of high carbon or alloy steels. These steels will, upon rapid cooling after hot working, retain austenite at temperatures below 400°F. Hydrogen held interstitially by the austenite is released at these temperatures, and builds up tremendous pressure in cooling steel. This causes rupturing or flaking in heavy sections which do not allow rapid diffusion of the gas. The only cure is slow cooling, allowing diffusion from pockets of segregation.

Hydrogen Embrittles Without Increasing Hardness, Strength

Another common effect of hydrogen is embrittlement of steel without increasing hardness or strength. Apparent cause is the ability of hydrogen to dislocate slip planes of strained crystals. Sources of hydrogen, in this case, can be either residual hydrogen or pickling solutions.

Defects in coated steel can also be traced to hydrogen. When a coating is applied hot, hydrogen from water vapor can be absorbed. This is released upon cooling, forming blisters in the coating.

There is some evidence, too, that hydrogen is the guilty party in steel corrosion. Hydrogen is also a source of porosity and bleeding in high-chromium stainless and low-alloy killed steels.

Hydrogen Has Many Entries, Few Exits

Hydrogen control thus assumes an important role in steel making. Most hydrogen is eliminated from the bath by a good boil . . . hydrogen pick-up occurs after the tap. Sources are moisture in the air, refractories and ferroalloys. Proper drying of refractories and alloys does much to relieve this situation.

Foote Electromanganese, An Effective Hydrogen Control

Since as little as 3 or 4 ppm of hydrogen in steel can cause trouble, ferroalloys are not above suspicion. A heavy ferroalloy addition containing 50 ppm hydrogen can make a significant difference. For applications where hydrogen is troublesome, Foote offers a grade of electrolytic manganese containing only 7½ ppm hydrogen.

For more information on Foote Electromanganese®, write for Bulletin 201, Foote Mineral Company, 424 Eighteen West Chelten Ave., Philadelphia 44, Pa.

FOOTE
MINERAL COMPANY

Circle 1117 on Page 48-B

Letters . . .

our metal laboratory. We were able to resolve our arguments with the superficient Rockwell and the microscope.

Since nobody else used a straight-edge razor, I was the recipient of several. The shop superintendent contributed perhaps the best edge I ever had – when it was sharp! That was the rub. At Rockwell C-64.5, as we found, it was just too hard to be amenable to stropping. We tested several razors which were C-58 to 61 – indifferent blades! We had an opportunity to test several razors which had been reground to remove nicks, and so on. They ranged from C-50 to C-58 unevenly. Our conclusion–regrinding ruins razors.

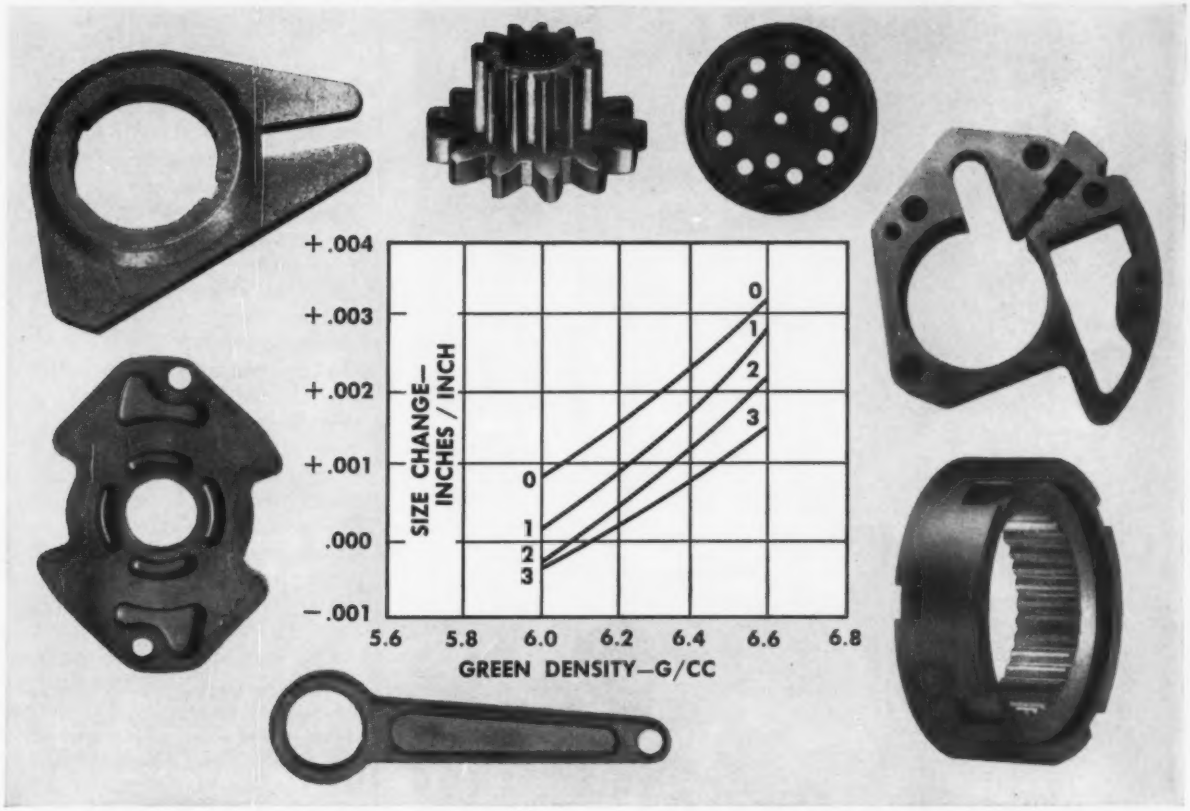
The laboratory supervisor gave me a razor he purchased in Brussels in 1917 which is perfect. It can be honed to a perfect edge, easily maintained by stropping. And it proved to be C-62!

But, of course, other people know razors should be C-62. During some length of time – a few years – while our studies of straight-edge razors were progressing, there arose a discussion about safety razor blades. One man brought us accounts, and later a sample, of what was supposed to be the nonpareil of safety razor blades. It was C-62. We then set about collecting samples of every kind of blade we could find. We found all were exactly C-62!

We were aware of Professor Honda's work in Japan on safety razor blades. Undoubtedly, by 1948, at the time of our sampling, the technology of safety blade manufacture was better standardized. At any rate, while we did not make the paper cutting test for sharpness, examination under the microscope classed all the blades we examined as being equally sharp, as well as of the same hardness.

FRED ARNOLD
Metallurgist

AUTHOR'S REPLY – The items submitted by Messrs. O'Leary and Arnold are interesting indeed. Mr. O'Leary adds to the history of our razor in that he definitely fixes the origin of the razor as England and not Germany. Not being an addict to the straight-edge razor, I cannot vouch for the effect of weather or



Better dimensional control, with economy ...when you use A.W. Iron Powder

Little differences in the carbon additive to A.W. Iron Powder can make big savings in your plant.

By use of different types of carbon additives, in iron-copper-carbon mixes, a broad range of dimensional control can be achieved. This provides not only greater latitude in design specifications, but prolongs the service life of your dies. Together, these advantages result in closer tolerances for your molded parts at reduced production costs.

The curves shown above indicate the range of dimensional change obtainable with various types of carbon. *The cost of all these grades is almost identical.*

The Alan Wood 50-ton-a-day direct reduction plant, backed by years of metallurgical research, offers you the most advanced technology in Iron Powder. Make Alan Wood your Iron Powder headquarters for dependable uniformity and delivery, as well as technical advisory service.

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CONSHOHOCKEN, PA.

FOR MORE INFORMATION

IRON POWDER DIVISION
ALAN WOOD STEEL COMPANY
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Please send me A.W. Technical Data Bulletin #3, which gives additional details on copper-carbon additives.

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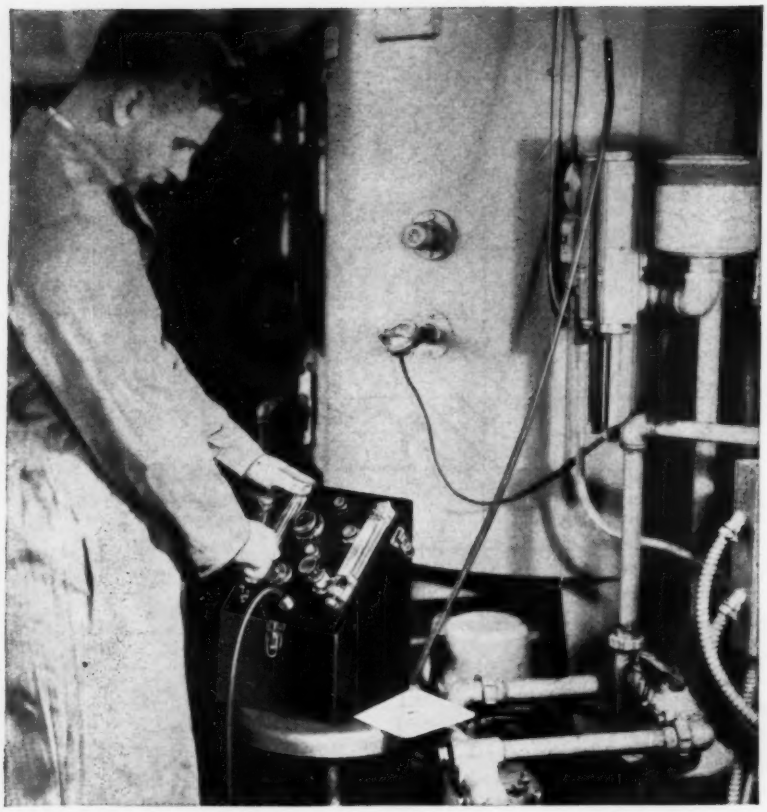
AMERICAN STEELMASTERS FOR 135 YEARS

Circle 1118 on Page 48-E



Necessary for controlled production in heat treating

Alnor DEWPOINTER®

for Determining Carbon Potential

The atmospheric condition in a heat treating furnace is accurately indicated by the Alnor Dewpointer. A sampling tube from the furnace connected to the Dewpointer makes it possible to check the carbon potential of furnace atmosphere almost instantly at any time during the process.

The Dewpointer can easily be disconnected and moved to other furnaces. The consistency of accurate readings by different operators on different furnaces is evidence of the reliability of the Dewpointer and the ease of operating.

To make a test, a sample taken from the furnace is put under pressure in the observation chamber and then released quickly to atmospheric pressure. If the expansion cools the gas below its dew point a distinctive fog is observed. This is repeated until the fog vanishing point is reached and the end point determined on the pressure ratio gauge. The exact dew point is indicated immediately. The model 7000-U Dewpointer is priced at $410.00.

Write for bulletin 2051

Alnor INSTRUMENTS

ILLINOIS TESTING LABORATORIES, *Inc.*
Room 523, 420 N. LaSalle St., Chicago 10, Ill., U.S.A.

Circle 1119 on Page 48-8

Letters . . .

usage on these tools, but I suspect that the personal equation must be quite prominent.

Mr. Arnold's experience evidently reinforces his belief that razors should be Rockwell C-62, although it would appear to me that a somewhat higher hardness would improve the ability to hold an edge. His conclusion that regrinding ruins razors, however, is at variance with the experience of my friend Mr. Wood, who had our ancient razor reground twice. Apparently the skill of the user in honing and stropping, and his dexterity in actual shaving, has a great deal to do with the evaluation of the blade. Mr. Wood, who started using this razor when he was in college (1900-1904), is so good at the job that, except for postoperative inspection, he has been shaving without a mirror for 35 years! He tells me that his present razor, which he started using a few years ago, is also quite old, since it came to him from a grand-uncle who died in 1892 at age 79. He has proposed to me that we examine it after he has used it for 50 years. So the readers of *Metal Progress* may expect another razor article shortly after the year 2000!

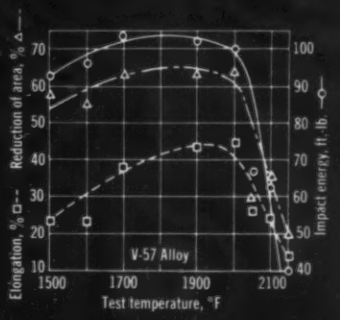
Forming and Finishing Aluminum Auto Trim

In the article under the above title in the July issue of *Metal Progress*, it was stated on p. 71 that the Stamping Div. of Eaton Mfg. Co., Cleveland, in its process of anodizing aluminum uses a 0.5% solution of nickel acetate in sealing the anodic coating and operates at a pH of 5.0. This should have read: "The division uses deionized boiling water only and operates at a pH of 5.5 to 6.5".

Heat Treating in the Fluid Bed Furnace

NEW YORK

We read with much interest the excellent article under the above title by Charles Bennett and Charles Jung of the Boeing Co., which appeared in the April 1961 issue of



Plot of tensile-impact properties indicates that the recommended hot working range of Carpenter's V-57 alloy in wrought form lies between 1700 and 2000°F.

fast, new test pinpoints best forging range for high temperature alloys

A fast, easy and economical, new Carpenter test takes much of the guesswork out of hot working high temperature alloys. The results, when correlated with other Carpenter test data and mill experience, reveal the best working temperatures—help forge shops get better finishes with less machine clean-up . . . less wasted steel . . . fewer rejects . . . faster fabricating.

Based on tensile-impact . . . Using a modified tensile-impact test method, impact strength, elongation and reduction of area in an alloy are determined over a range of temperatures. By plotting tensile-impact properties as a function of temperature, the hot working range of the alloy can quickly be established. (see chart)

New, improved Carpenter techniques and quality controls like this, are your best assurance of easy forgeability and consistent uniformity in high temperature alloys. For details, or data on Carpenter's VACUMELTROL® and CONSUMET® vacuum melted products, call your Carpenter representative today.

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Export Dept., Port Washington, N.Y.—"CARSTEELCO"
Alloy Tube Division, Union, N.J.
Webb Wire Division, New Brunswick, N.J.
Carpenter Steel of New England, Inc., Bridgeport, Conn.

Circle 1120 on Page 48-B

Th-Mg: ONE REASON WHY VITRO'S RARE EARTH CHEMICAL / METAL ALLOY SALES ROSE 34% IN 1960.

There must be good reasons for this growth. And there are—consistent high quality backed by research. Perhaps Vitro's product development department can assist you. Do you have production difficulties adding alloy components or face burn-up problems where the use of master alloys can be effective? Vitro quality control provides guaranteed uniformity and offers end-product consistency. ■ In addition to thorium-magnesium master alloy, Vitro has developed several rare earth and related family alloy combinations. Its technical staff is anxious to join with you in formulating new alloy combinations and special custom blends. They also can supply pure metals of the rare earth family. Write today for complete technical literature and please feel free to discuss any specific research or production problem without any obligation. Address Product Development Department F.

Vitro's thorium-magnesium master alloy is extensively used in our nation's expanding missile effort. Some 40% of the "skin" on the USAF Titan missile is thorium-magnesium alloy.

Vitro CHEMICAL COMPANY
a Division of Vitro Corporation of America
261 MADISON AVENUE • NEW YORK 17, NEW YORK
Circle 1121 on Page 48-B

Letters . . .

Metal Progress, p. 82. However, since our division processes and markets zirconium oxide and zirconium silicate, we question the cost of $6.00 per lb. given for zirconium oxide in Table I on p. 84. This reported cost seems somewhat excessive, even when freight charges to the West Coast are considered.

FRANK M. STEARN
Sales Development Engineer
Titanium Alloy Mfg. Div.
National Lead Co.

AUTHOR'S REPLY: As you note, the $6.00 per lb. cost for zirconium oxide quoted in the article on fluid-bed furnaces is incorrect. We normally consider the cost of zirconium oxide to be $1200 per ton or approximately $.60 per lb.

Brazing . . .

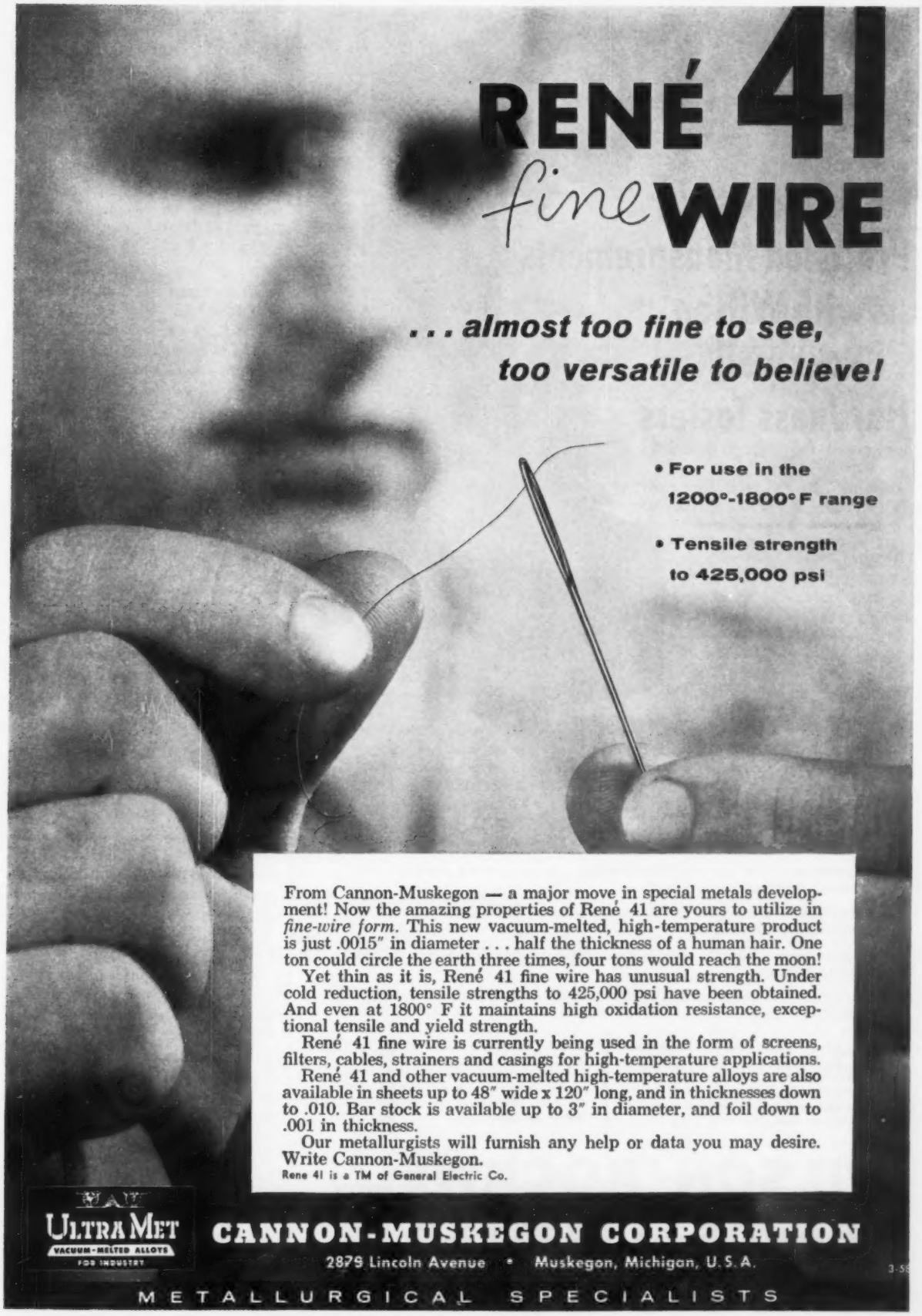
(Continued from p. 105)

must be closely controlled to optimum values.

Brazing Alloys – From the multitude of potential brazing alloys, we at Boeing have narrowed the necessary stock of filler metals to about seven (Table I). A considerable range of properties and brazing conditions exists in a particular brazing alloy specification such as A.M.S. 4775. Trade names, brazing temperatures, atmospheres, and times should be specified on drawings to insure adequate quality control.

The use of special pre-mixed alloy pastes has simplified brazing alloy placement, minimized alloy waste and eliminated undesirable residues in the joint. Applying the paste with an air-pressure sealant gun or a plastic syringe dispenser gives best results. Acrylic-powder mixtures are occasionally used for deep-placement lap joints, and powder-polyvinyl alcohol strips and shims are employed for specialized applications.

Brazing Atmospheres – For all base metals except those superalloys containing high aluminum and titanium – such as René 41, R-235 and 713 C – the best braze flow, joint quality and strength are obtained with pure, dry hydrogen atmospheres (−90° F dew point, or


RENÉ 41
fine WIRE
. . . almost too fine to see,
too versatile to believe!
• For use in the 1200°-1800° F range
• Tensile strength to 425,000 psi

From Cannon-Muskegon — a major move in special metals development! Now the amazing properties of René 41 are yours to utilize in *fine-wire form*. This new vacuum-melted, high-temperature product is just .0015" in diameter . . . half the thickness of a human hair. One ton could circle the earth three times, four tons would reach the moon!

Yet thin as it is, René 41 fine wire has unusual strength. Under cold reduction, tensile strengths to 425,000 psi have been obtained. And even at 1800° F it maintains high oxidation resistance, exceptional tensile and yield strength.

René 41 fine wire is currently being used in the form of screens, filters, cables, strainers and casings for high-temperature applications.

René 41 and other vacuum-melted high-temperature alloys are also available in sheets up to 48" wide x 120" long, and in thicknesses down to .010. Bar stock is available up to 3" in diameter, and foil down to .001 in thickness.

Our metallurgists will furnish any help or data you may desire. Write Cannon-Muskegon.

Rene 41 is a TM of General Electric Co.

VAC ULTRA MET
VACUUM-MELTED ALLOYS FOR INDUSTRY

CANNON-MUSKEGON CORPORATION

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3-58

METALLURGICAL SPECIALISTS

Circle 1122 on Page 48-B

Easy Operation, Precision Measurements ...with Wilson "Rockwell" Hardness Testers

• No matter what your hardness testing requirements are, there's a Wilson Rockwell instrument to do the job easily and accurately. Long recognized as the world's standard of hardness testing accuracy, Wilson instruments on the production line and in the laboratory offer these advantages:

Accuracy—Each instrument is precision-built, with exact calibration, for consistently correct results.

Easy operation—Even an unskilled operator can get perfect readings. All controls conveniently grouped.

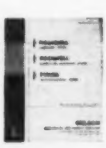
Long life—Simple design, rugged construction make Wilson instruments as durable as a machine tool.

Easy maintenance—Interchangeable mechanisms, with spindles mounted in oil-less bearings.

Complete line—Choose from the widest variety of instruments available, including semi and fully automatic models.

Wilson "Brale" Diamond Penetrators Each diamond is cut to an exact shape. A comparator check and microscopic inspection of each diamond assure perfect readings every time.

Write for details—Ask for Catalog RT-58. It gives complete information on the Superficial tester as well as on the full line of Wilson Rockwell hardness testers.



WILSON "ROCKWELL" HARDNESS TESTERS

Wilson Mechanical Instrument Division
American Chain & Cable Company, Inc.
230-F Park Avenue, New York 17, New York

ACCO

Circle 1123 on Page 48-B

Brazing . . .

drier). This atmosphere is satisfactory for brazing precipitation-hardening alloys with lower aluminum and titanium such as Incoloy 901 and A-286. As previously discussed, a dry argon atmosphere (from a liquid-argon source) combined with a flux activator has proven best for brazing René 41, R-235 and 713 C. In general, braze quality improves with higher atmosphere-gas flow rates because of the rapid removal of contaminants. Aluminum content appears to be the critical factor with respect to requirements for brazing atmosphere.

Brazing Equipment – The brazing furnace should have adequate heating capacity to bring retort and braze load from the solidus temperature of the braze alloy to brazing temperature within 10 to 15 min. This will produce smooth braze fillets and full joint flow. Retorts sealed with fused alundum or pure silica sand allow higher gas flow rates and therefore yield cleaner, stronger braze joints than weld-sealed retorts used with or without vacuum purging. Atmosphere gas should be introduced through a heat-resistant alloy diffuser and flow rates should be in the range of 15 to 25 volume changes per hour.

Brazing Cycles – To produce strong, ductile joints, we specify a 20 to 30 min. holding time at brazing temperature to diffuse boron-silicon compounds through the joint and base metal. This treatment breaks up the fine eutectic and boride network and is particularly important where the feed fillet is in a highly stressed area.

For brazed joints where maximum ductility is needed, or where subsequent welding near or over the brazed joint is performed, a 3-hr. diffusion treatment in argon at 2000° F. is employed. This diffusion has an appreciable effect on hardness in the brazed joint, as shown in Fig. 4, p. 104. Figure 5 (p. 105) illustrates the amount of diffusion that occurs in a typical brazed joint as a result of holding at high temperature.

Testing Brazed Joints

In our first attempts to fabricate components for small gas turbines, we found that simple, reliable test procedures were needed to evaluate process variables and provide data

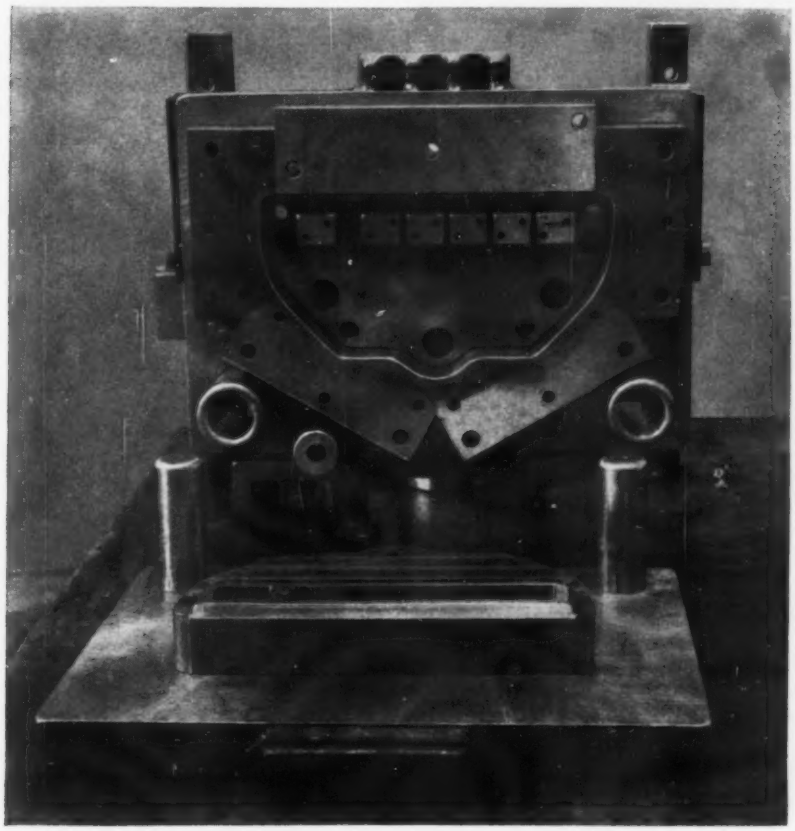
Steel

Tool Steel Topics

BETHLEHEM STEEL

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Export Sales: Bethlehem Steel Export Corporation



Bethlehem Brake Die Tool Steel Forms Vacuum-Cleaner Base Plate

At Remmele Engineering, Inc., St. Paul, Minn., they needed a tool steel with high strength to handle a difficult forming operation on sheet steel. The part, a base plate for a vacuum cleaner, was produced by a die made of Bethlehem Brake Die tool steel.

Engineers at Remmele liked Brake Die's well rounded combination of fine mechanical properties. They also found it a time saver because it machined so readily. Best of all, it produced thousands of pieces before slight redressing was required.

This tool steel requires no heat-treatment

Brake Die is ideal for intricate bending and forming dies because it combines high wear-resistance with high strength. It requires no additional heat-treatment because it is furnished in the heat-treated condition, ready for machining into a finished die. Brake Die is quenched and tempered in our shop to develop its superior properties. Then we straighten it mechanically and give it a stress-relief-anneal to remove straightening stresses.

Your Bethlehem tool steel distributor has Brake Die on hand in many sizes and sections, ready for prompt delivery. Give him a call today.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

For Uniform Service from Tools, Control the Surface Chemistry

One of the most difficult problems in the use of tools is non-uniformity of service life. Absolute uniformity in production from all identical tools is not expected. But wide variations in service life from one tool to another, or from one lot to another, present a real problem.

It has been found that the most frequent cause of non-uniform service is the variation of chemistry on the tool surfaces. Small amounts of surface carburization or decarburization usually are unnoticed because they can be detected only by destructive testing.

Decarburization on working surfaces of tools causes a decrease of normal service life. And varying amounts of decarburization from tool to tool will cause variable decreases in service life.

Carburization, on the other hand, is not always harmful. Many tools last longer if a carburized case of the optimum depth and carbon content is present. This is true whether the carburized case is intentional, or whether it is accidentally and unknowingly present. The extent to which a carburized case either increases or decreases service life of tools must be determined by experience with the actual tools under consideration. It is therefore possible for tools with a "neutral" surface to be either better or poorer in service life than tools having a carburized case.

The surest way to provide uniform surface chemistry is to grind the tools adequately after the hardening operations. The only alternative is to be sure that "neutral" heat-treatment equipment is actually doing the expected job of providing unground hardened tools with neutral surfaces.

Circle 1124 on Page 48-B

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FABRICATED HEAT AND CORROSION RESISTANT ALLOYS

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AND GRIDS

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Standard for use in L & N furnaces.

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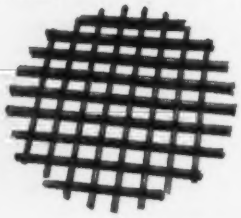

Customer "X" (name on request) is just one who reported such practical savings as "one extra eight-hour cycle per week."

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JOB-ENGINEERED for better work
Easier Operation, Lower Cost

3R161

Circle 1125 on Page 48-B

Brazing . . .

on optimum brazing techniques. Some of the variables associated with heat-resistant brazing alloys are flowability, application temperature, remelt temperature, base-metal erosion, oxidation resistance, gap-filling characteristics and joint strength. We found that the most informative and practical specimens for process evaluation were the simple and restrained-T types and circular-pillow pressure test specimens. These provided good data on joint ductility, strength, diffusion characteristics and relative brazing characteristics of various alloys. The circular-pillow pressure test (Fig. 6) is also an excellent process control for individual retort lots. The specimen is sensitive to retort leaks, to variations in alloying and surface preparation, and to purity of brazing atmosphere.

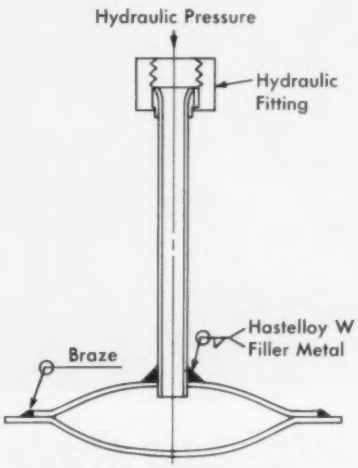
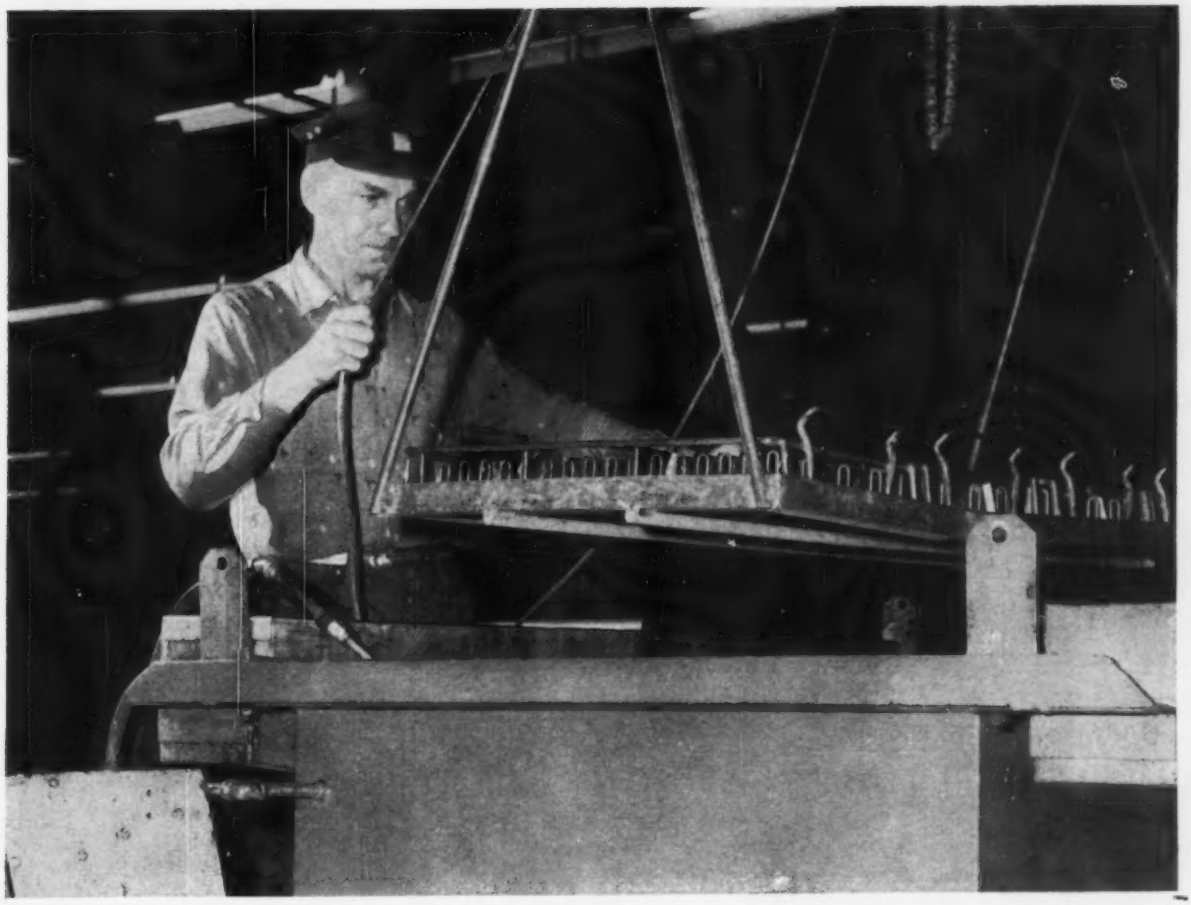


Fig. 6 — Cross Section of 3-In. Diameter Circular-Pillow Specimen After Testing. Failure occurs when either the base metal or brazed joint ruptures or leaks as a result of increasing hydraulic pressure

Room and elevated-temperature properties (shear and tensile) are best evaluated by Peaslee-type shear specimens and butt tensile specimens. Another promising tool for evaluating braze joints is photoelastic stress analysis (see *Metal Progress*, November 1960, p. 111). Destructive testing of simulated joints has also been highly informative for design purposes.



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Approximately a year ago, the Metals Processing Division, Curtiss-Wright Corporation, began using high-quality Hooker NIALK® TRICHLORETHYLENE to degrease jet engine blades. Before this, maintaining purity in the baths required frequent cleanouts. Chemical costs were high.

Immediate results with Nialk showed a better cleaning job and tighter quality control. Down time for degreaser maintenance has been substantially reduced.

The exceptional cleaning results now obtained permit inspectors to discover possible flaws more easily. Maintaining quality is far less difficult.

The stabilizer in Nialk TRICHLOR contains *psp*—permanent staying power—which enables the stabilizer to operate efficiently until cleanout. After cleanout, the solvent is distilled for further use in other operations.

Curtiss-Wright officials say that the assistance they obtain from Hooker technical experts in preventing waste is most important, since they are working with costly metals. Because the degreasing baths have never turned acid, problems in keeping their quality at a high level and the necessity to run tests have been reduced. Whatever your degreasing job or the type of metal you're processing, Nialk TRICHLOR can give you a greater volume of work and reduce your costs, as well as provide a smooth-running operation.

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Circle 1126 on Page 48-E

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Circle 1127 on Page 48-B

Deformation of Metastable Austenite

(References for article on p. 68)

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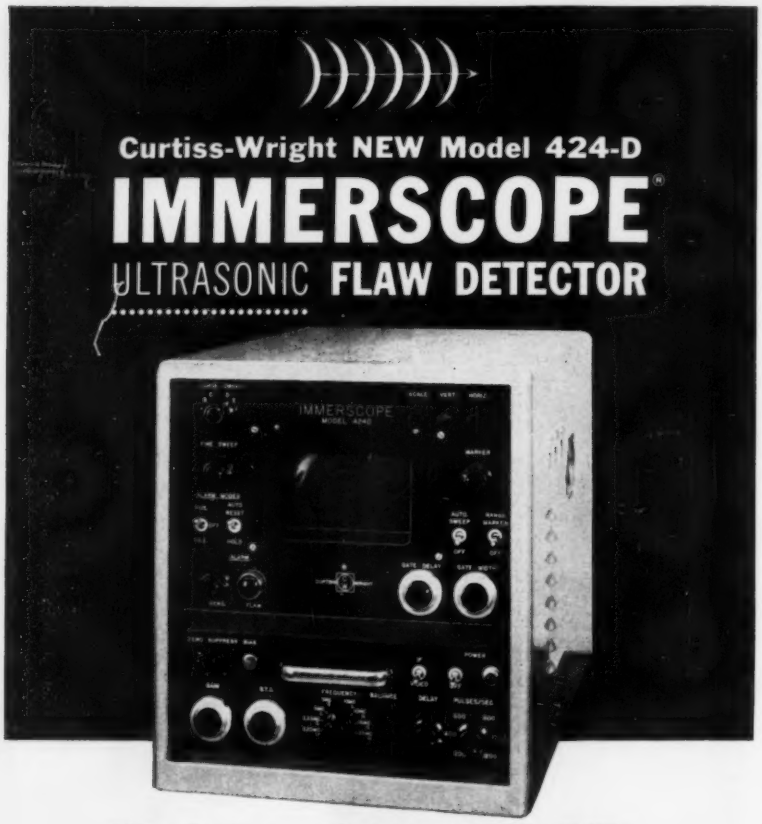

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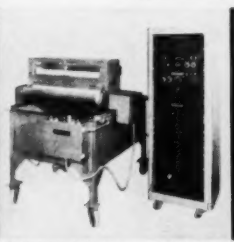
Manual Package—Model PT1001
Manually operated bridge and scanner, precision manipulator, Immerscope, search tubes, transducers and standard size tank (4' long x 3' wide x 18 in. deep).



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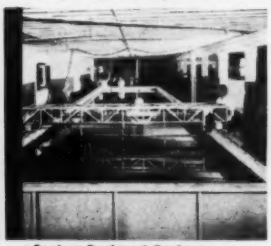

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Circle 1129 on Page 48-B

"Hot Box" . . .

(Continued from p. 112)

shaft, one end of which extends through an insulated seal in the end wall, the other terminating inside the chamber with a flanged hub. This hub contains a hole pattern that mates with a hole pattern on one end of the welding fixture to allow the inert gas to enter. The other end of the hollow shaft connects with the supply of inert gas through a coupling outside the chamber.

A support that can be moved anywhere along the full length of the chamber is used to position the other end of the welding fixture. This support contains a free-turning flanged hub on the same axis as the hub on the motor-driven positioning shaft. The bulk of the weight of the welding fixture and work to be welded is taken by rollers supported from the bottom plate of the chamber. These rollers are adjustable, so that they may be positioned to contact circular sectors incorporated in the various welding fixtures. For heating, the chambers contain four banks of tubular elements that can raise a maximum load of 1600 lb. to 600° F. in 30 min. and heat it to 1200° F. for stress relieving in 1 hr.

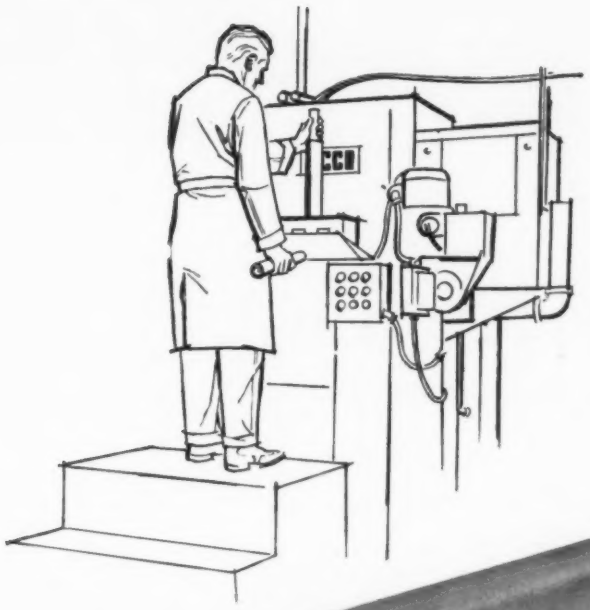
Mobile power units supply current for the heating elements. Each unit contains four indicating controllers, four output receptacles, and four thermocouple connectors.

Phosphating . . .

(Continued from p. 111)

should be uniform and not blotchy or sparkling.

Manganese phosphate coatings are produced by dipping or some modification of dipping with immersion periods of about 10 to 30 min. at 190 to 205° F. Obviously, such processing conditions bar the use of spray washers. The process requires a minimum of five dip stages which usually include a hot alkaline cleaner, hot water rinse, phosphating, cold water rinse, and inhibitive chemical rinse. Additional stages are needed if pickling is required. The operation proceeds in much the same manner as in zinc phosphate dip systems. Phosphating can be carried out in mild steel



TOCCO Induction Hardening Boosts Track Pin Production 10 Times

The Eimco Corporation of Salt Lake City are producers of heavy-duty earth moving and mining equipment. They recently replaced a low production induction hardening method with a modern, more efficient track pin hardening machine engineered and built by TOCCO for high production operation.

Production Jumped from 208 pins per shift to over 2000 using only one operator. Powered by a 200 KW 3 KC TOCCO motor generator, the new machine produces parts of higher uniform quality with correspondingly better results in service.

Additional Saving is obtained because TOCCO's new continuous roll feed machine does not need center holes in the pins, eliminating two centering operations on each pin.

It will pay you to have a TOCCO sales engineer review your heat treating applications. He can help you boost production and cut costs by the engineered application of induction heating.

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Circle 1130 on Page 48-B

Now—Finishes Add Beauty to Tough Malleable Castings

Beautiful, protective finishes on tough Malleable iron castings will give your products a superior combination of appearance, ruggedness, and economy. Get complete information on this sales-getting combination from any of the progressive companies that display this symbol —

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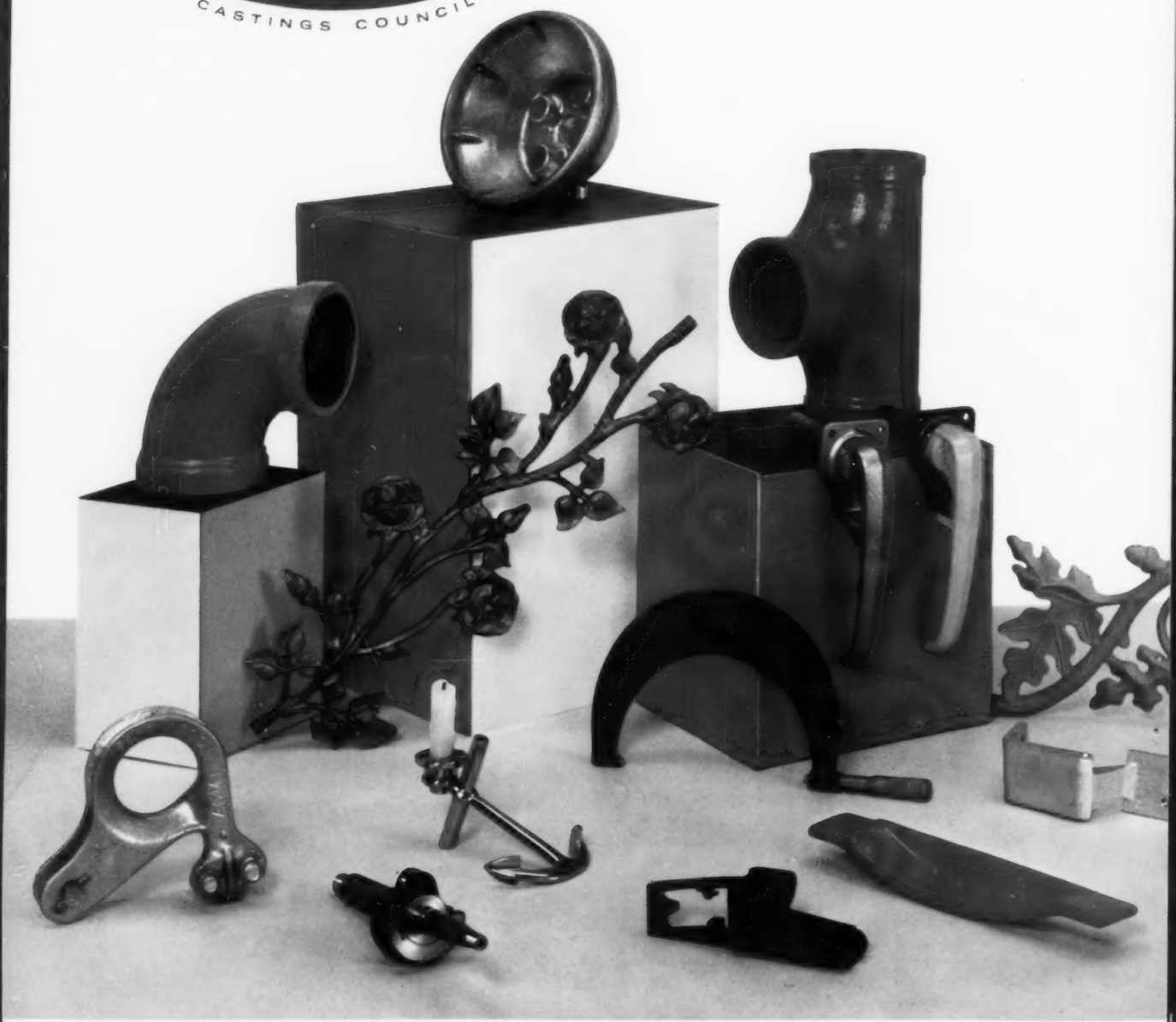
New Ideas for your products are suggested in Data Unit No. 115, available free from any member of the Malleable Castings Council, or write to Malleable Castings Council, Union Commerce Building, Cleveland 14, Ohio.



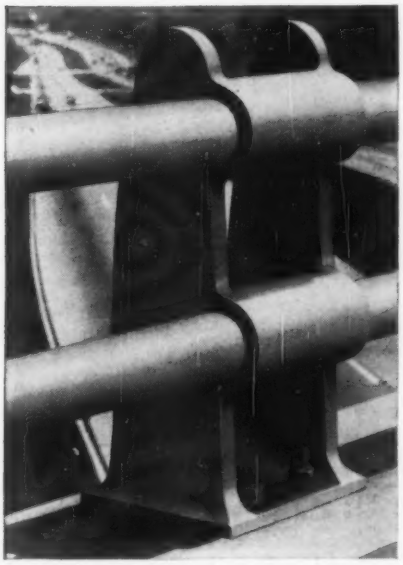
The castings shown have been painted, blued, chromium and cadmium plated, plastic coated, porcelain enameled, galvanized, and machined.

When appearance and long service life are important to your products, Malleable castings offer many advantages. Painting, hot dip galvanizing, blueing, and electroplating have long been used with Malleable castings because of their economy, attractiveness, and resistance to a variety of destructive conditions.

Several exciting new finishes appear very promising and are currently being tested by Malleable producers. Vinyl plastic in thin, contour-hugging films or thick, resilient coatings provide exceptional chemical resistance, and are available in a wide spectrum of strikingly beautiful colors.

Another attractive finish is porcelain enamel. In addition to smooth, gleaming surfaces in unlimited colors, it has excellent resistance to heat and chemicals.

The variety of fin[illegible] which can be successfully applied to Malleable gives desi[illegible]rs outstanding opportunities to combine decorative and protective surfaces with the rugged dependability, economy, and versatility of Malleable castings. Call your Malleable supplier for information and quotations.



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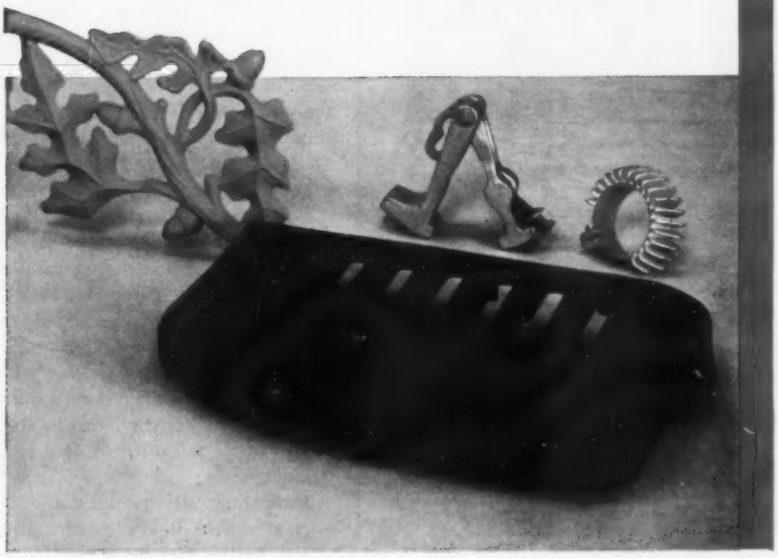

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Circle 1131 on Page 48-B

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Experienced engineers and purchasing agents long ago discovered "you get exactly what you pay for" when buying gas generation equipment.

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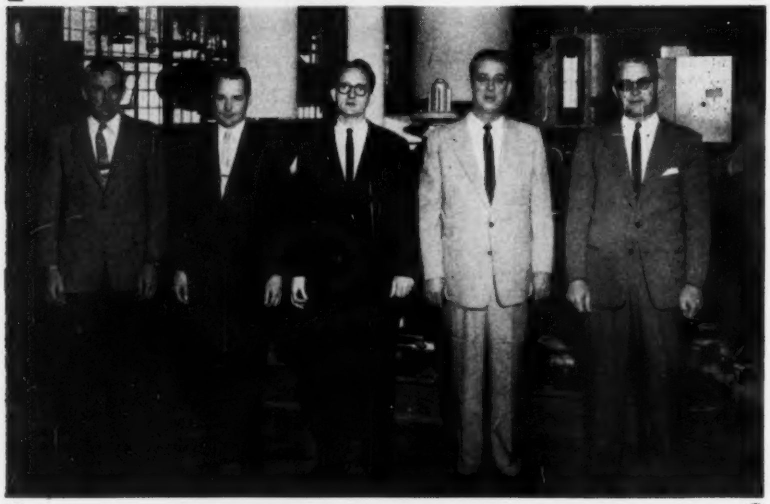

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4234

Circle 1132 on Page 48-B

Phosphating . . .

tanks but because of the greater concentration of the bath and higher operating temperature, it is preferably performed in stainless steel tanks.

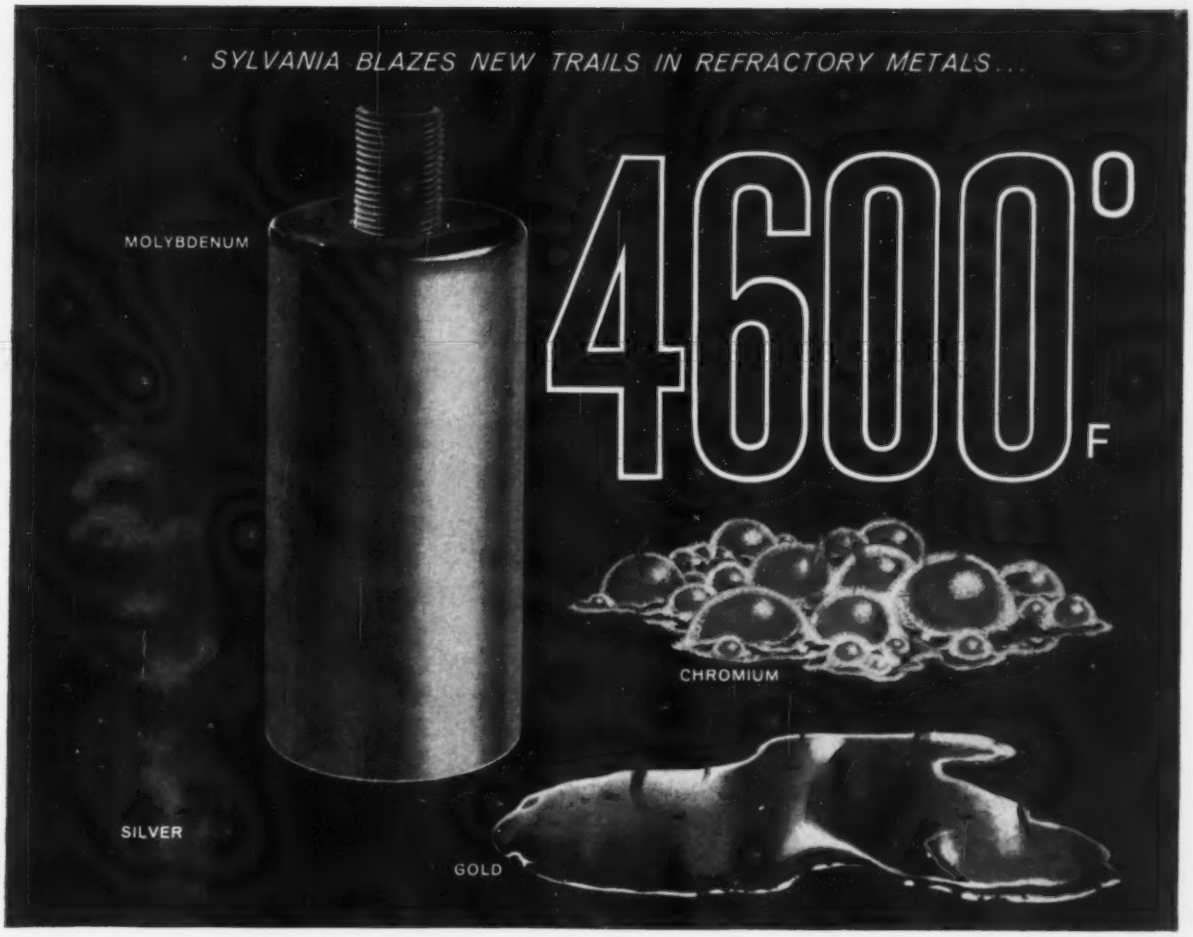
Surface Preparation

Production of thick coatings which are uniform and not blotchy or sparkling requires careful preparation of the surface. Much manganese phosphating work is done under government specifications which require that the surface be prepared by sand-blasting or other form of abrasion. The abrasion procedure should be followed by vapor degreasing or cleaning in a mild alkaline bath (followed by a rinse) to remove grease residues. There appears to be a wide-spread practice among military contracting officers, however, to grant waivers in this respect in favor of phosphoric-acid pickling. Other forms of pickling are quite often authorized. In many instances, good work is accomplished without any pickle treatment or abrasion at all.

Careful attention must be given to the selection of a cleaner. Particularly when special alloys of steel are employed, it is advantageous to use an activator in the cleaning bath. Where pickling or other acid treatment is performed, the parts should be dipped in an activator bath after being pickled and before phosphating. A hot water rinse must be provided after the cleaner, cold water rinses after each of the other stages.

A straight manganese phosphate compound has some tendency toward instability in the package after some months of storage, but there is likely to be no difficulty of this kind in periods of less than six months storage. However, after the compound has become really old there may be a gradual separation of pale pink crystals on the bottom of the container which may become quite voluminous. The compound will be still usable however, provided the crystals are stirred up before adding any compound to the working bath. If well stirred to make it reasonably uniform, the compound can be used to replenish the bath just as a fresh product.

Manganese phosphate baths are used at much higher concentration



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SYLVANIA

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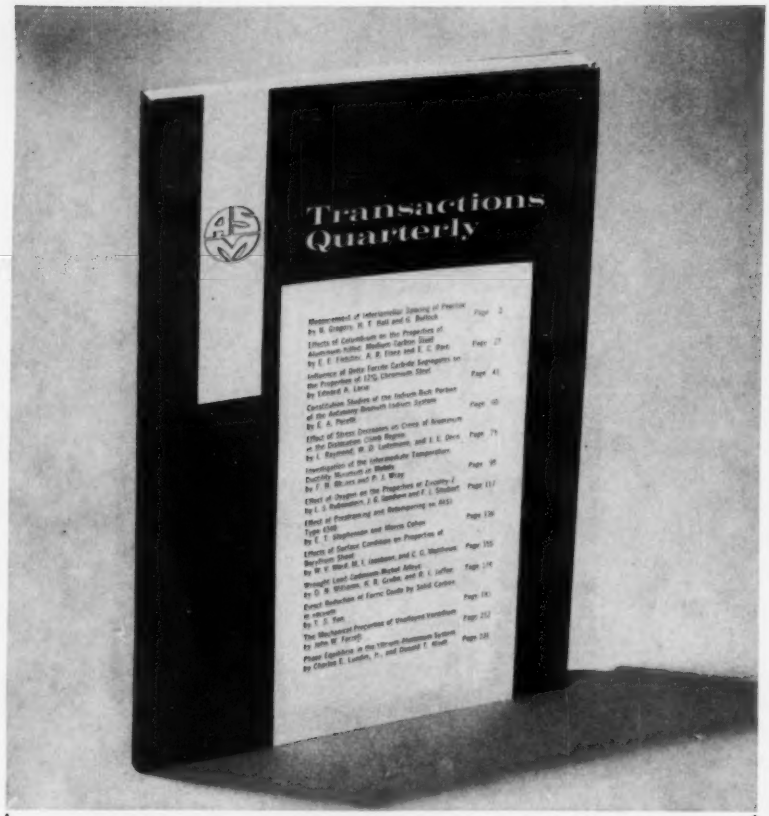
Circle 1133 on Page 48-B



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Phosphating . . .

than the others – 6 to 10 gal. per 100 gal. of water instead of 2 or 3 gal. For best quality, it is essential to have a relatively high proportion of ferrous iron in solution; 0.2 to 0.4% is good. It is, therefore, necessary to give careful attention to the break-in procedure, preferably starting with 6 oz. per 100 gal. of ferrous phosphate powder, followed by a generous treatment with steel wool, powdered iron, scrap iron or old sludge, to build up the ferrous iron content.

Heavy Work Load Is Best

The manganese phosphate bath operates to best advantage when heavily worked every day on rather small parts, especially those of the softer steels, thus permitting considerable dissolution of iron. This maintains the ferrous iron content at optimum level. When possible, production should be scheduled so that the bath works continuously every day, with frequent replenishment of the chemicals. It is not good to run through a few pieces and then let the bath lie idle for a day or so before resuming work. Under such conditions, the bath is likely to lose some of its ferrous iron and perform less efficiently. When daily operation is not possible, the bath should be worked continuously for a few days and then permitted to lie idle for a few days. When resuming operation after days of idleness, it may be advantageous to add ferrous phosphate powder at the rate of 6 oz. per 100 gal. of bath, or

DISTORTION IN TOOL STEELS

This practical, easy-to-read book by Bernard S. Lement helps you understand and remedy the size and shape changes in tool steels which occur during and after processing . . . with emphasis on methods of heat treatment for precise dimensional control. All tool steel users will find this volume a valuable source of useful and usable information. *173 p. -- illustrated – 6x9 – cloth-bound–ASM members $8.00/non-members $10.00/overseas postage $1.00.* Clip and mail to Technical Books Dept., ASM, Metals Park, Novelty, Ohio.

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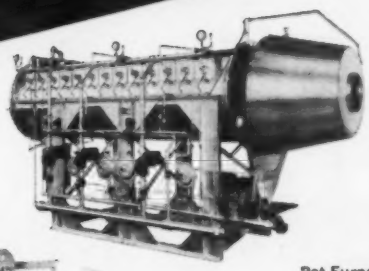
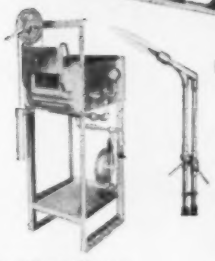


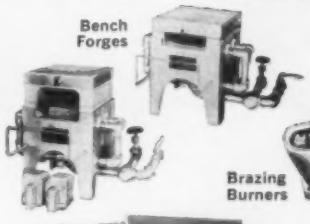
Continuous and Batch Rotary Furnaces

Pot Furnaces



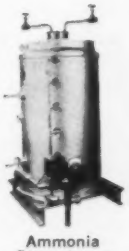
Hand Blow Pipes

Bench Forges

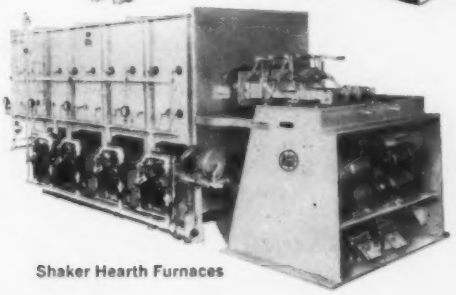


Tool Room Ovens

Brazing Burners



Ammonia Dissociators



Shaker Hearth Furnaces

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RUSH ME AGF'S 607 CATALOG
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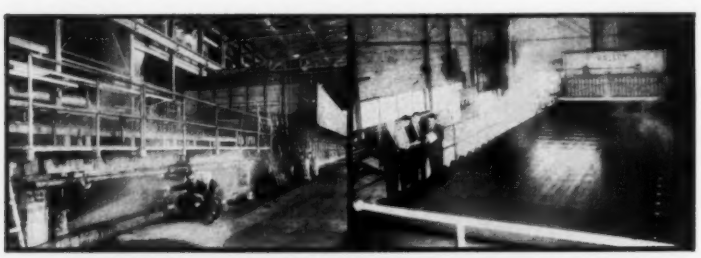
The photomicrograph above, made from an etched .009" cross section of a new composite stainless alloy and phosphor bronze wire, was one of Fort Wayne Metals most closely guarded secrets since 1957; and well it might have been.

Used in Fourdrinier paper machine wire screen belts up to 200 feet long and as wide as a two lane highway, it is responsible for a major cost reduction in the multi-billion dollar paper industry.



Paper makers (many running their block-long Fourdriniers 24 hours a day) who once had four-hour shutdowns every week from wire failure—at a cost up to $1,000 an hour—now run as long as a month or more without wire trouble, even 102 days under special conditions. FWM's Drawn Brazed Strand ("DBS") provides the extra fatigue life and better chemical resistance required to bring about this saving.

"DBS" can be produced in a composite of many different types of alloys for diversified uses, including physical, thermal, chemical, magnetic, electronic and electrical applications. "DBS" may prove to be an important development in many products where high fatigue resistance, light weight, chemical inertness, controlled conductivity or combinations of these characteristics are required.

"DBS" development is typical of the ideas in precision alloy wire you can expect from FWM. We will be glad to forward "DBS" data on request.

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3211 MacARTHUR DRIVE
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Circle 1136 on Page 48-B

Phosphating . . .

to apply the other break-in methods as with a new bath. In this respect, manganese baths differ considerably from those of zinc phosphate.

Tests and Controls

Manganese baths are less stable than the others; hence it is essential to exercise vigorous control and vigilance at all times. Titrations for free and total acid to find the ratio, and determination of ferrous-iron content should be made frequently.

Manganese baths have a tendency to form excessive sludge. This is a normal operating feature and there is little or nothing that can be done to prevent it. Careful attention must be given to frequent sludge removal and to the relation between bath volume and the surface areas to be processed. With a bath of generous volume, there is less danger of contamination.

Quality of Coatings

The difficultly most likely to be encountered with manganese baths is contamination of the coating with white streaks, blotches or scums. Another defect may be formation of coarse crystals that have a sparkling appearance. Should these defects occur, one should check acid ratio, preparation of the surface, time of immersion and temperature and the position of the workpieces in the bath. Are they hanging freely with plenty of free liquid around each piece, with the bottom well off the bed of sludge, the top of the workpiece well immersed and the significant surfaces in a vertical position? Is there enough ferrous iron in the bath? Close adherence to all of the control ranges (particularly the acid ratio) set forth in operating instructions is imperative. When blotchy coatings appear, it is well to have the acid ratio down toward the lower end of the control range, adding phosphoric acid if necessary to accomplish this. Regular and frequent replenishment with the chemical is also essential.

Iron Phosphating Next

In the November issue of *Metal Progress*, the important characteristics of iron phosphate systems and how to get best results from them will be described.

Straight-Line Temperature Control

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Used with a conventional Self-Balancing Recorder or Indicator, and a transmitting slide-wire, the Thermo Electronic Proportional Controller functions as a time-proportioning device. It combines high performance and operating simplicity at a lower initial investment. Outstanding Features include . . .

Minimum Overshoot – Sensitive and continuous adjustment of control action as the set-point is approached prevents overshoot. Your processes are rapidly brought to set-point and closely maintained.

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Simplified Operation – Only two, non-critical adjustments are necessary – the proportional band and the load range. The conventional, highly critical, reset function adjustment has been eliminated. 100% proportional band adjustment provides widest control action.

Wide Application – Any process using on-off or high-low temperature control is accurately regulated with this Proportional Controller. These include electric furnaces, band or zone heaters on plastic extruders, solenoid valves, and others. The instrument can directly actuate control devices, or can be used to actuate a load relay.

High Accuracy – Electrical accuracy is ¼ of 1% of controller span, as related to accuracy of primary instrument.

The Thermo Electronic Proportional Controller is a unique concept in design for instruments of this type.

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Circle 1137 on Page 48-B

PERSONAL MENTION

Falih N. Darmara

Italo S. Servi

FALIH N. DARMARA, well-known for his work on vacuum induction melting, is president of Special Metals, Inc., a new firm which recently purchased the Metals Div. of Kelsey-Hayes Co. in New Hartford, N.Y. Formerly general manager and president of the division, Mr. Darmara had been chief executive of the Metals Div. since its inception in 1952 when Kelsey-Hayes acquired Utica Drop Forge and Tool Corp. He was graduated from Izmir College (1932) in his native Turkey, then went on to graduate studies at Harvard and Massachusetts Institute of Technology, where he received his master's and doctor's degrees. In 1941 he joined Utica Drop Forge and Tool as chief metallurgist, leaving in 1945 for a short term as research metallurgist for the National Advisory Committee for Aeronautics, then a two-year advisory assignment with U. S. Steel Corp. He returned to Utica in 1949 and a year later was named assistant to the president, then vice-president of the organization.

ITALO S. SERVI, former technical director of the Metals Div., is vice-president of the new company. A specialist in behavior of metals at high temperatures and in corrosive environments, Dr. Servi is a 1946 graduate of the University of Milan in Italy with a degree in industrial chemistry and holds a master's and doctor's degree from Massachusetts Institute of Technology. He joined Union Carbide Metals Co. in 1951 as a research metallurgist and was manager of the corporation research group when he joined the Metals Div. in 1959.

A member of many technical groups, he was chairman of the Columbium and Tantalum Applications Panel and a member of the Refractory Metals Committee, for the Materials Advisory Board of the National Academy of Sciences.

JOHN S. HUNTINGTON, formerly technical assistant to Mr. Darmara, is now a vice-president in charge of all special development and production projects. He was chiefly responsible for the design, development and construction of most of the present furnace equipment. A graduate with a B.S. degree in metallurgical engineering from Rennselaer Polytechnic Institute, he joined the Fairchild Engine & Airplane Corp. in 1942 as a research engineer, then in 1944 became a member of the National Advisory Committee for Aeronautics in the same capacity, returning to Fairchild in 1946 and remaining there until he joined Dr. Darmara in 1952.

One of the pioneer members of the Metals Div., HARRY J. HAMJIAN, now vice-president directing operation of seven vacuum induction furnaces, had been manager of plant operations since 1945. A graduate of the University of Michigan with a B.S. in chemical engineering (1944) and an M.S. in metallurgical engineering (1947), he was an aeronautical research scientist for the National Aeronautics and Space Administration in Cleveland, then joined the Metals Div. as a research metallurgist, later becoming manager of powder metallurgy. He was directly connected with all new alloy developments, including the well-known Udimet series.

Several ASMembers, leaders in the field of engineering materials, were recipients of Award of Merits from the American Society for Testing Materials at the Society's annual meeting in Atlantic City, N.J. Awards were made to:

Thomas E. Eagan, chief research metallurgist for the Cooper-Bessemer Corp., Mount Vernon, Ohio, in recognition of his outstanding contributions to the field of ferrous metals, particularly in Committee A-3 on Cast Iron, and for administrative support as committee secretary and chairman.

Russell B. Gunia, manager, stainless steel metallurgy, U.S. Steel Corp., Pittsburgh, in recognition of his efforts in the establishment and promotion of workable specifications, particularly in Committee A-

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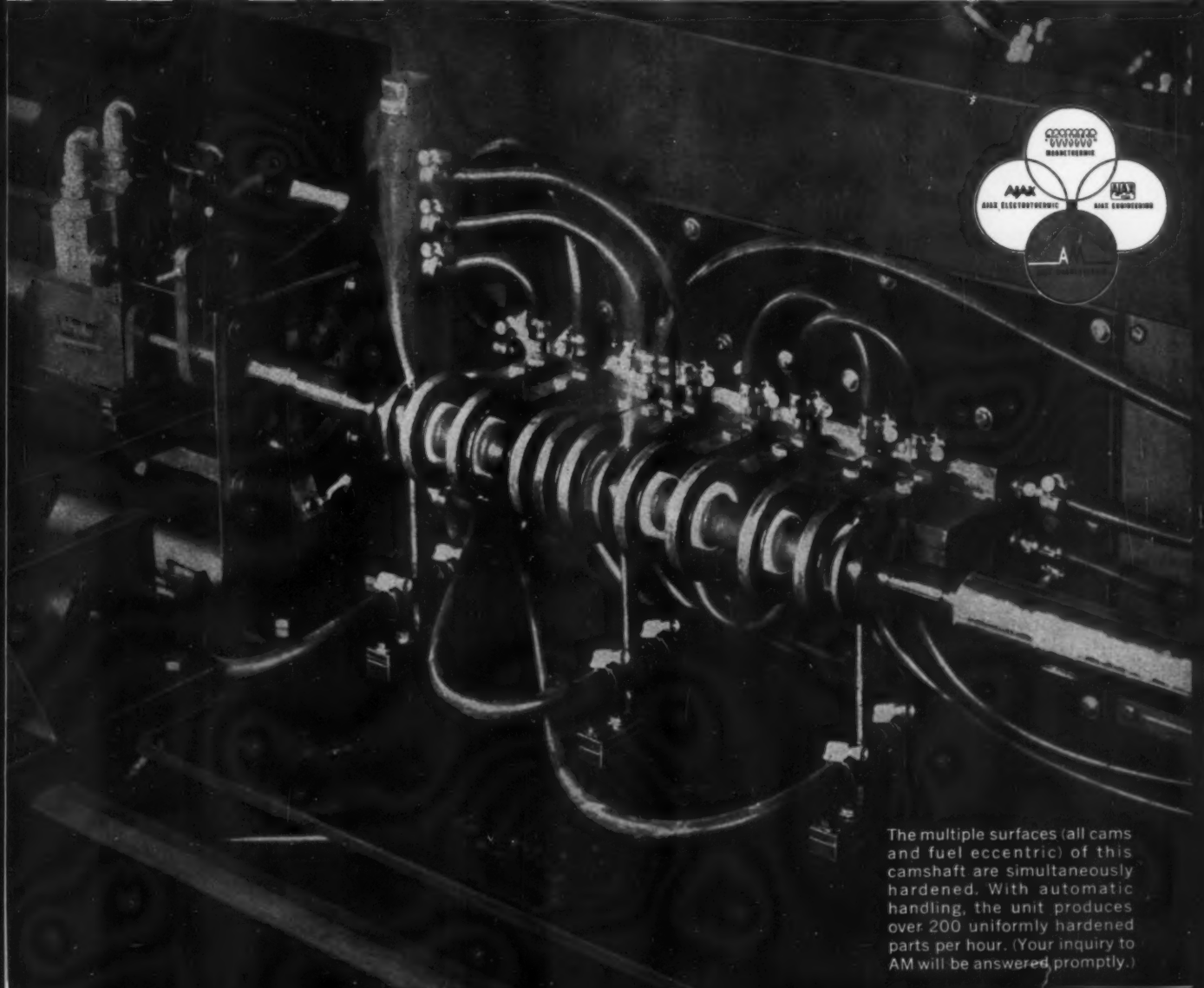
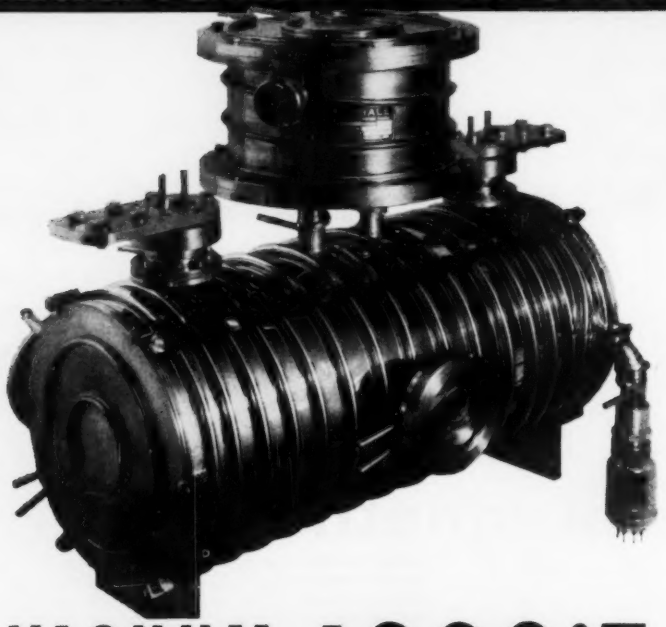


The multiple surfaces (all cams and fuel eccentric) of this camshaft are simultaneously hardened. With automatic handling, the unit produces over 200 uniformly hardened parts per hour. (Your inquiry to AM will be answered promptly.)

Marshall Furnaces at Union Carbide

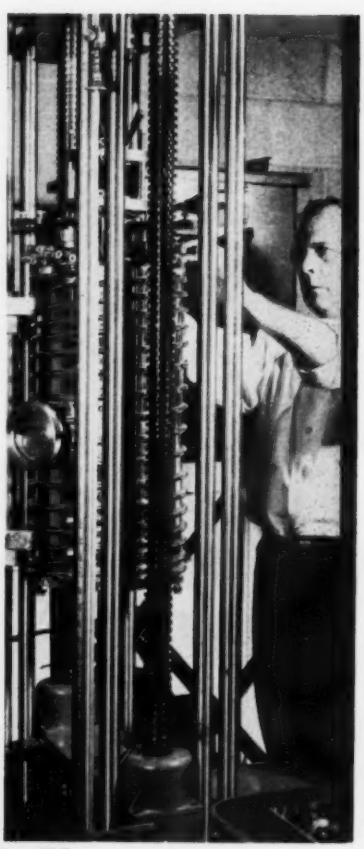


VACUUM TESTS TO 4000°F

Marshall Furnaces, specially designed for Union Carbide Metals Company, Niagara Falls, N.Y., make possible vacuum tests at temperatures to 4000° F. In tensile machine (right), furnace creates temperatures to 4000° F. at pressures less than 0.2 micron to test tungsten, tantalum, and columbium base alloys. Dynamic Moduli Furnace (above) produces up to 4000° F. for vacuum dynamic moduli tests.

These very specialized furnaces are evidence of Marshall's unique experience and capabilities in designing and building high temperature testing equipment.

Marshall also offers standard tubular, resistance wound, shunt-type furnaces for test uses to 2600° F. in air. Furnaces feature uniform temperature or regulated temperature gradient, and rigid zone control to ±1½° F. Models from 1" to 12" ID or more, and a few inches to several feet long. Complete packages can include furnace, vacuum equipment, temperature control and electrical equipment, support stands and brackets. Write for literature. MARSHALL PRODUCTS CO., 270 W. LANE AVENUE, COLUMBUS 2, OHIO (Phone AX 9-4159).



MARSHALL FURNACES

Circle 1138 on Page 48-B

Personals . . .

10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys.

Francis M. Howell, retired chief of the mechanical testing division of Alcoa Research Laboratories in New Kensington, Pa., in recognition of long and constructive participation in the work of Committee B-7 on Light Metals and Alloys, Cast and Wrought, and for services in administrative and district work.

James H. Lansing, castings consultant (retired consulting engineer, Malleable Founders' Society, Cleveland), in recognition of long and devoted participation in the field of cast metals, notably in Committee A-7 on Malleable-Iron Castings of which he is serving his 14th year as secretary, and for administrative and district activities.

John S. Worth, metallurgical engineer, Bethlehem Steel Co., Inc., Bethlehem, Pa., in recognition of sustaining and significant contributions to the development of standards, especially in Committee A-1 on Steel.

Don B. Cartwright – appointed assistant sales manager, Walmil Co., Detroit, a division of the Duraloy Co. Scottdale, Pa.

Philip S. Hanson – named product development engineer at the Beryllium Corp. of Reading, Pa.

E. C. Bishop – from engineering manager to technical coordinator at the Westinghouse Electric Corp. metals plant in Blairsville, Pa.

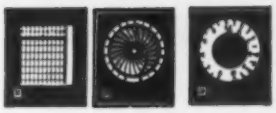
W. Michael Yim – after receiving a doctor of science degree from Massachusetts Institute of Technology, joined the Tonawanda Laboratories of Linde Co., a division of Union Carbide Corp. in Tonawanda, N.Y.

John R. Link – appointed general manager of Ward Hydronics Ins., a subsidiary of Scott Aviation Corp., Alden, N. Y.

Clarence J. Tobin – retired after more than 36 years as a researcher, consultant and metallurgical processing expert at General Motors Research Laboratories, Detroit. Since 1933 he had been assistant head of the laboratories metallurgical engineering department.

ALL-NEW *ElectroniK 17* POTENTIOMETERS

HAVE NO SLIDEWIRE, NO SLIDEWIRE PROBLEMS

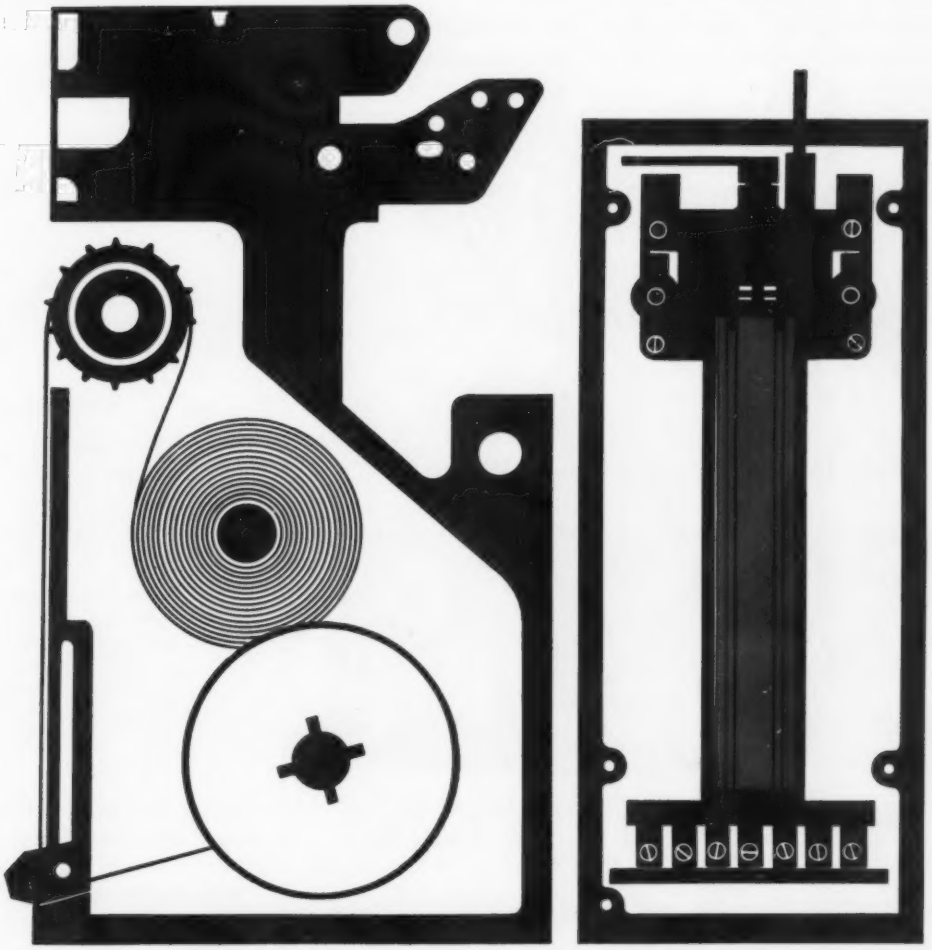


Here is a totally new kind of potentiometer with a totally new kind of measuring system. The *STRANDUCER* replaces the slidewire, and sets a new high standard for potentiometer performance. The new *ElectroniK 17* potentiometers have calibrated accuracy of ±0.25%.

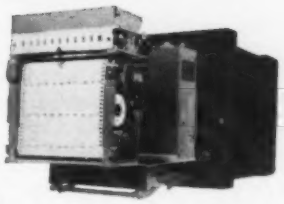
In addition, modular construction makes *ElectroniK 17* instruments easiest of all potentiometers to operate, convert and maintain. Full interchangeability of components cuts service time and spare parts requirements.

You can get *ElectroniK 17* instruments as strip or circular chart recorders or circular scale indicators. You can get electric contact control with up to 8 contacts. All control units are of convenient plug-in type. For all the eye-opening facts about this new class of instruments, call your nearby Honeywell field engineer, or write MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Phila. 44, Pa.—In Canada, Honeywell Controls, Ltd., Toronto 17, Ont.

The unique *STRANDUCER* rebalancing element works on the proven strain gage principle. Both *STRANDUCER* and pen carriage are linked to the potentiometer balancing motor. A change in electrical input causes the balancing motor, to change the tension—and electrical resistance—of the *STRANDUCER*, to reposition the instrument pen or pointer. The *STRANDUCER* is unaffected by corrosive atmospheres and has no contactors. It has unusually long life and infinite resolution and is unaffected when the instrument operates in ambient temperatures up to 130° F.



True modular construction saves you time, trouble, money. Three basic modules—case, display and drive—make up the *ElectroniK 17*. The case fits standard 19-inch relay racks. You can remove the door easily and without tools when converting from strip chart to circular chart or circular scale operation. You can pull out the chassis to the service position without tools, and without interrupting operation, or remove it completely. Up to 8 contact control modules can be plugged in for a variety of control possibilities.



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Circle 1139 on Page 48-B

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EAT IT?

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Circle 1140 on Page 48-S

Personals . . .

John B. Ulam – named president of Composite Metal Products, Inc., Washington, Pa.

Kenneth H. Swart – from president of Smith Tool Co., a division of Smith Industries, to executive vice-president and general manager of Smith Industries International, Inc., Compton, Calif.

Joseph A. Staricenka – from research and development engineer for M & C Nuclear, Inc., a division of Texas Instruments, Inc., Attleboro, Mass., to research metallurgist, fiber metallurgy section, at Fram Corp., East Providence, R. I.

Philip W. Snyder – retired as rear admiral, vice-chief of naval material in the Navy Department and joined the Grace Line, New York, as technical director in the executive offices of the president.

Walter F. Schneid – retired as vice-president and general manager of Eastern Stainless Steel Corp., Baltimore, Md. He will continue as a member of the company's board of directors and will also be retained in an advisory capacity.

Simon A. Prussin – from project leader, materials research at Pacific Semiconductors, Inc., Culver City, Calif., to president of MonoSilicon, Inc., Gardena, Calif.

Fred S. Price – appointed eastern sales representative for the Advance Foundry Co., Dayton, Ohio.

Eugene A. March – from director of technology to vice-president of technology at Crucible Steel Co. of America, Pittsburgh.

Edwin S. Phillips, president, E. S. Phillips Co., Wilkinsburg, Pa. – appointed regional representative of Designers for Industry, Inc., in southwest Pennsylvania and West Virginia.

Norman A. Matthews – now group leader, ferrous metallurgy, at the International Nickel Co. research laboratory in Bayonne, N. J.

John C. MacLeod – from director of operations at the Barrett Div. of Allied Chemical & Dye Corp., New York, to the newly created position of vice-president for operations.

ONE MAN HANDLES 16 TONS/HR. AND UP ON THIS DREVER WIDE PLATE HEAT TREATING LINE

IT'S A LONG WALK from end to end of this approximately 500′ Drever Continuous Wide Plate Heat Treating Line at the Houston plant of the Sheffield Division of Armco Steel Corporation. But, one man controls the entire processing of alloy steel plate from his air conditioned booth. He is helped by hook men at each end of the line and by an overhead crane operator, but while the plate is being treated he has complete pushbutton control combined with closed circuit television and phone intercommunication.

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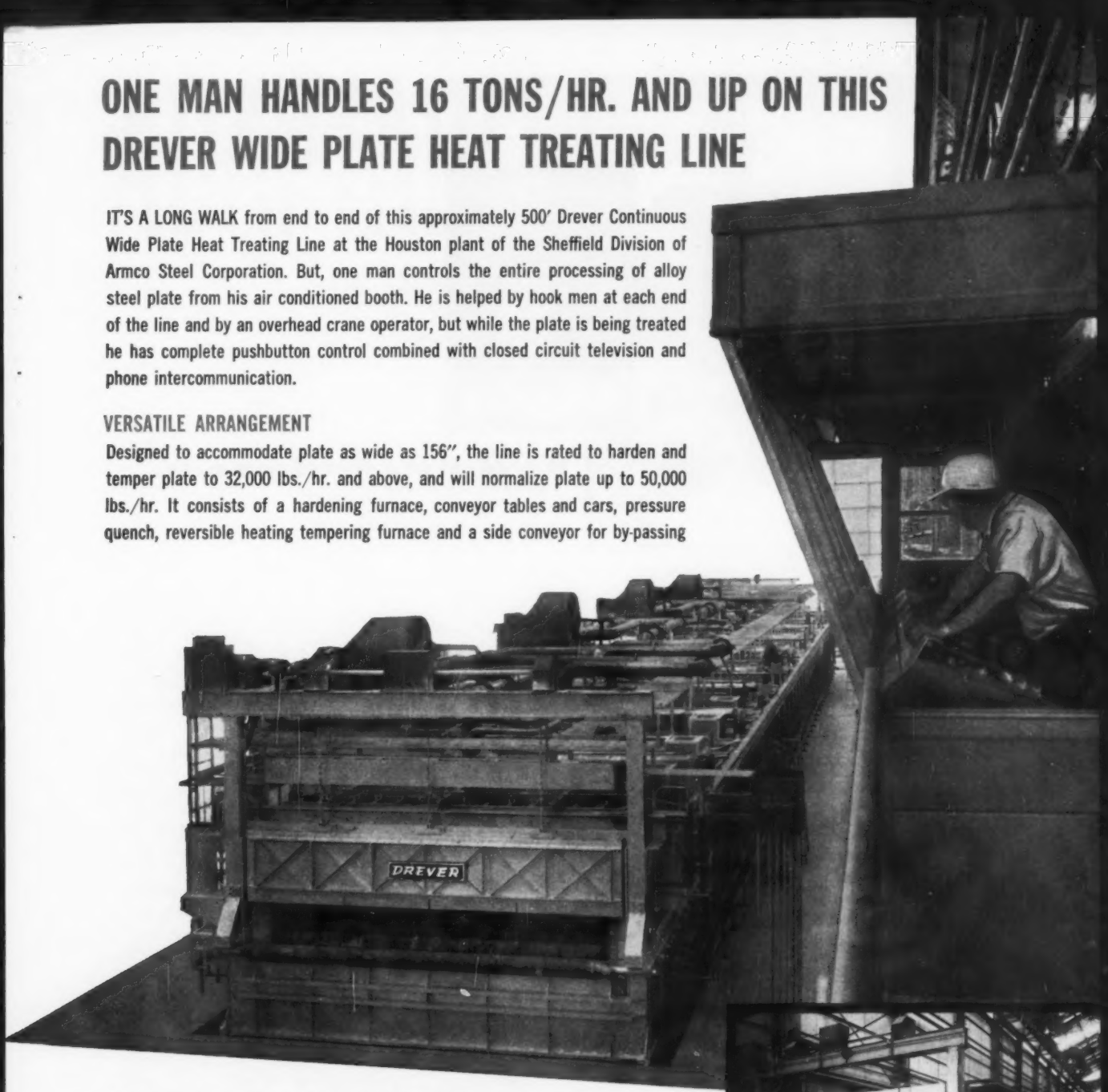

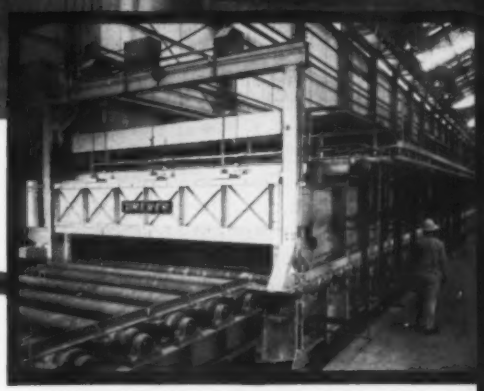

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Metals Engineering Digest

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"Metals for Today and Tomorrow" . . . an A.S.M. Seminar at Monterey

Reported by ROBERT C. BERTOSSA*

On scientific and industrial fronts, work is going forward on refractory metals, magnetic materials, and metals for semiconductors. These three topics were thoroughly discussed by distinguished technical men at this important West Coast meeting.

ON APRIL 29 AND 30, the Golden Gate Chapter sponsored its fifth annual seminar. At this important meeting, held in conjunction with the U. S. Naval Postgraduate School in Monterey, Calif., 115 scientists and engineers heard timely and significant discussions concerning "Metals for Today and Tomorrow". The first of three interesting talks (which covered the properties of refractory metals, magnetic materials, and metals for semiconductors) was given by Julius J. Harwood of the Ford Motor Co. According to the speaker, "Research on refractory metals is advancing with ever-increasing intensity to meet missile and space requirements for strength at elevated temperatures".

Mr. Harwood defines a refractory metal as a metal which melts above 3400° F. – this group includes tungsten, rhenium, osmium, tantalum, molybdenum, hafnium, ruthenium, iridium, columbium, rhodium, vanadium and chromium. The refractory metals most widely considered today (molybdenum, columbium, tantalum and tungsten) have the body-centered cubic structure; major difficulties in using them involve developing low-temperature ductility, high-temperature strength, and oxidation resistance. Concerning ductilities at low temperatures, Fig. 1 shows that tantalum and vanadium have very little tendency toward a radical ductile-to-brittle transition temperature range. Conversely, columbium and molybdenum show transitions (below 32° F.), and chromium and tungsten both have high ductile-to-brittle transitions (between 550 and 750° F.).

Researchers have learned that impurities in columbium raise its transition temperature. In fact, over-all ductility in these metals appears to be a function of purity, scientists having observed that the addition of impurities increases their yield strengths and causes brittle fracture and ductile-to-brittle transitions to occur at higher temperatures. Furthermore, effects vary with the refractory metal being tested. Small amounts of impurities raise the transition temperatures of molybdenum and tungsten several hundred degrees, but have much smaller effects on columbium and tantalum. In part, this results from the greater solubility of interstitial elements in vanadium, columbium, and tantalum as compared with their solubilities in chromium, molybdenum and tungsten.

Working Refractory Metals

Because of these characteristics, impurities must be low. Also forgers and extruders of refractory metals must carefully control deoxidation practice and be certain that all fabrication is done above the transition temperature. Because molybdenum, tungsten, rhenium, and chromium also have strain-harden-

*Technical Director, Pyromet Co., San Carlos, Calif.; Consulting Editor, *Metal Progress*.

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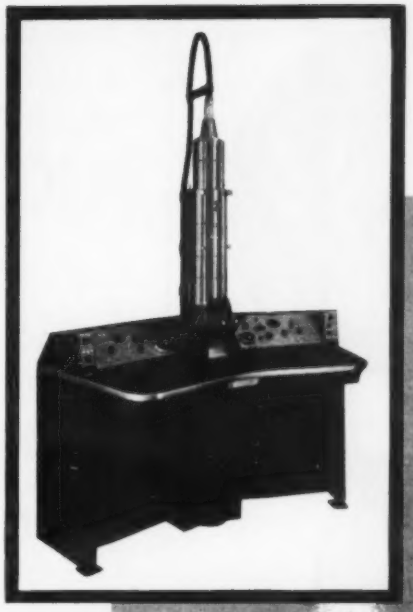

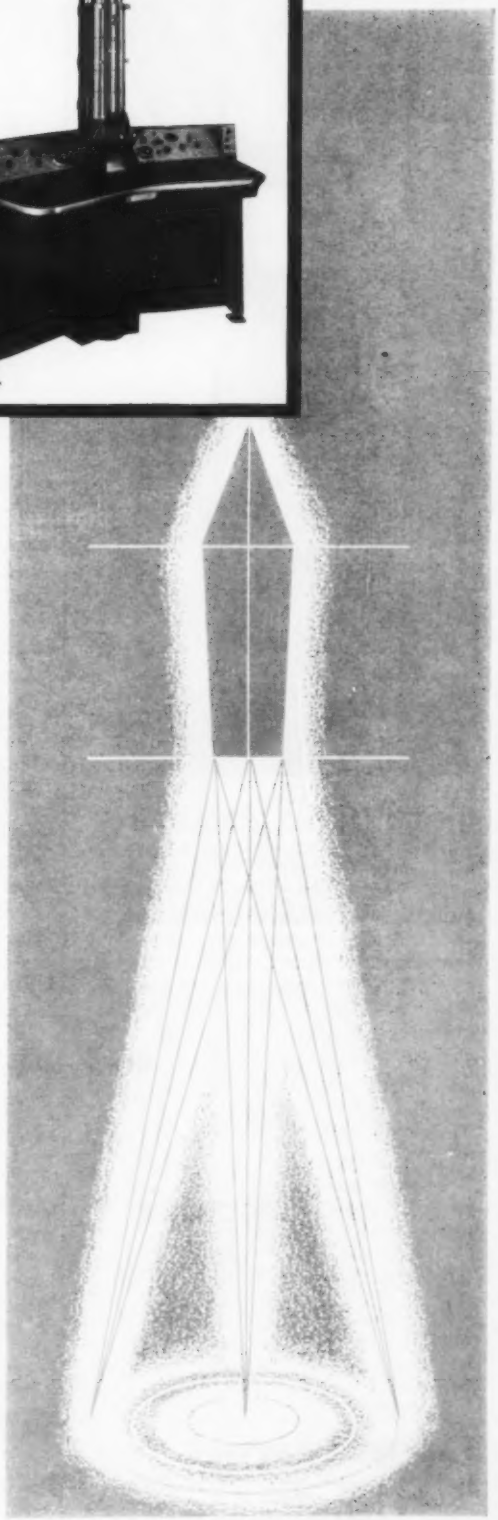

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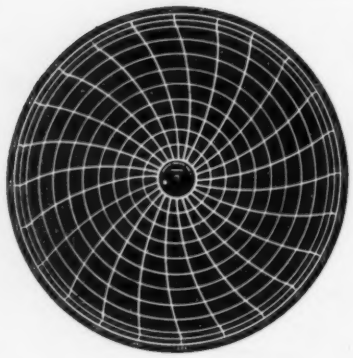

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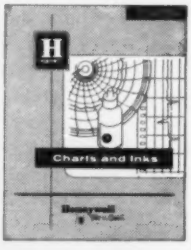

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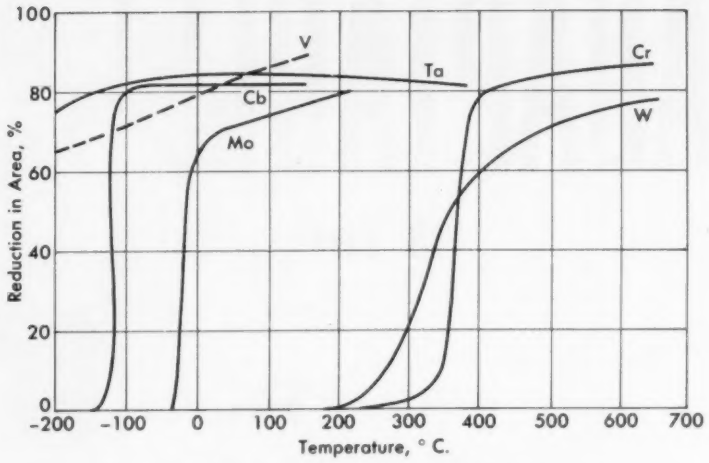

Fig. 1 — Tensile Transition Ranges for Recrystallized Refractory Metals. This Westinghouse information shows that chromium and tungsten have comparatively high ductile-to-brittle transition ranges, a characteristic which makes it necessary to work them at fairly high temperatures. The other refractory metals can be processed at somewhat lower temperatures

ing characteristics, they require intermediate annealing during working. Tantalum and columbium, however, can be worked at ambient temperatures if they are high enough in purity.

Since rhodium is a face-centered cubic metal and thus not susceptible to brittleness at low temperature, it is ductile down to −190° C. (−300° F.). Ruthenium and osmium have shown embrittlement at ambient temperatures; however, these effects may be due to impurities. As research progresses on refractory metals, researchers will find (according to Mr. Harwood) that fracture characteristics do not depend on grain size. Though this has not yet been definitely proved, results of present work indicate such a trend.

High-Temperature Properties

As might be expected, the high-temperature properties of refractory metals are superior to those of all others, even though they are not as high as might be expected from the melting points. In fact, their high-temperature strengths must be increased by strain hardening or by alloying. According to Mr. Harwood, high-temperature strengths of these refractory metals are a function of their melting points. That is, the higher the melting point of the metal, the higher its elevated-temperature strength will be. The reason? High-temperature processes are controlled by thermal activations involving atom diffusion, dislocation phenomena, and certain other effects. Dorn, of the University of California, has done work which indicates that the energies of activation for creep, stress-rupture, and self-diffusion correlate with the melting points for all metals. This would seem to confirm the "homologous temperature" theories discussed by Portevin and others in past years. (See "A Homologous Temperature Scale for Metals", by J. H. Westbrook, *Metal Progress*, September 1960, p. 100.)

In line with this, resistance to recovery and recrystallization are also thermally actuated processes involving atom diffusion. These are important factors in determining high-temperature properties, since the strength of the metal decreases rapidly when recovery and recrystallization occur.

Importance of Oxidation Resistance

Notwithstanding the difficulties connected with achieving high-temperature strengths, oxidation resistance (or lack of it) is still the most important problem in the use of refractory metals. Of them, chromium is the most oxidation resistant, but even it absorbs nitrogen

(Continued on p. 152)

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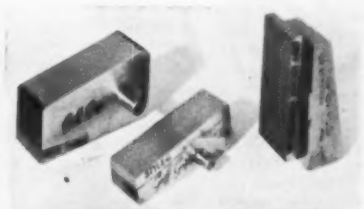

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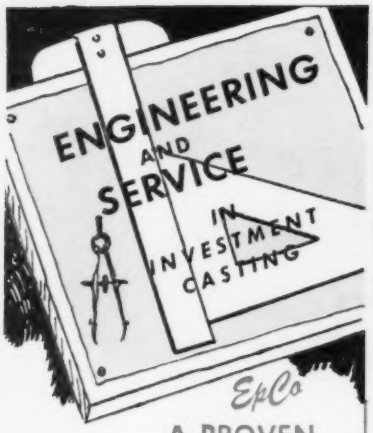

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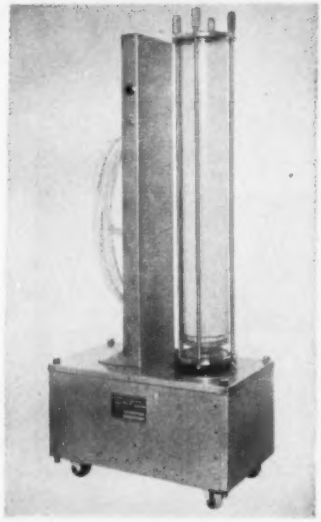

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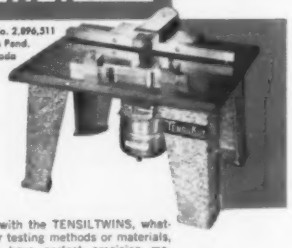

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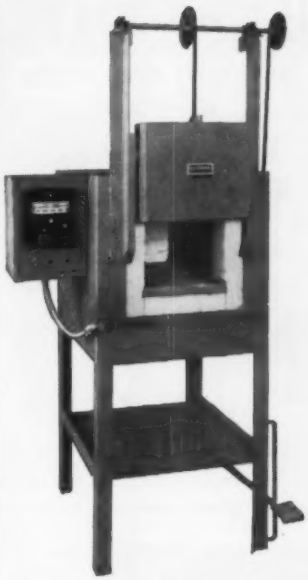

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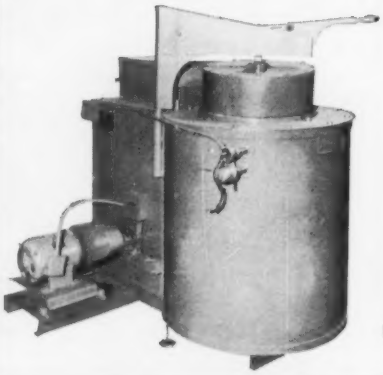

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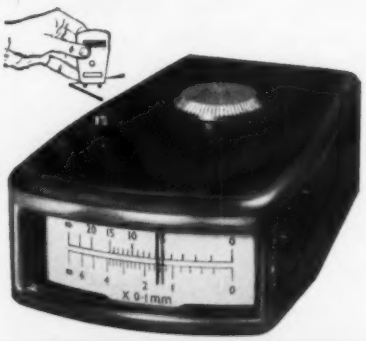

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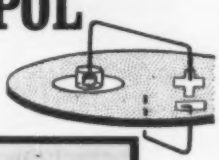

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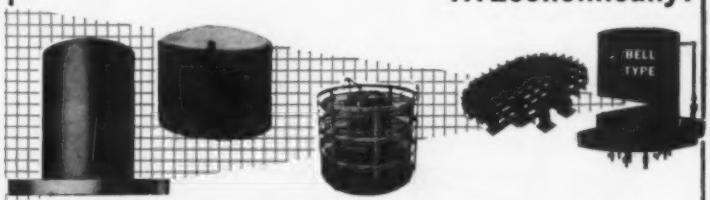

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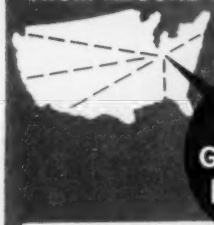

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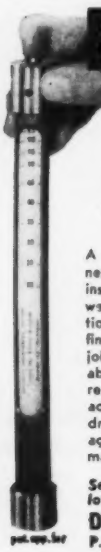

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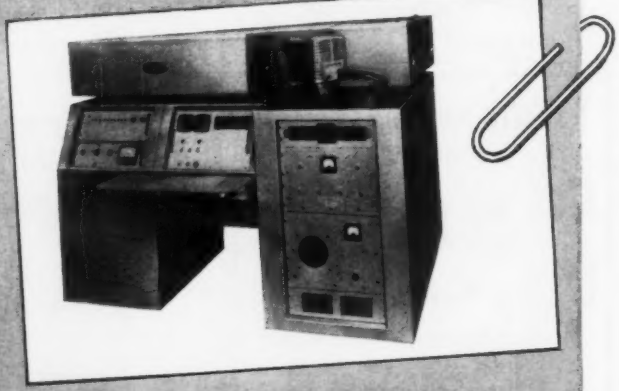

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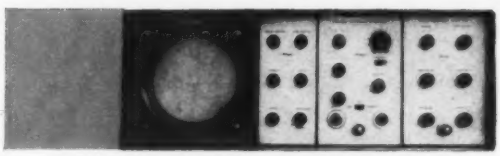
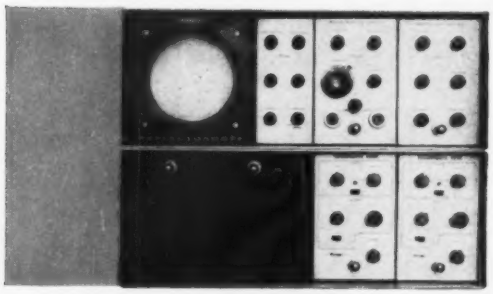
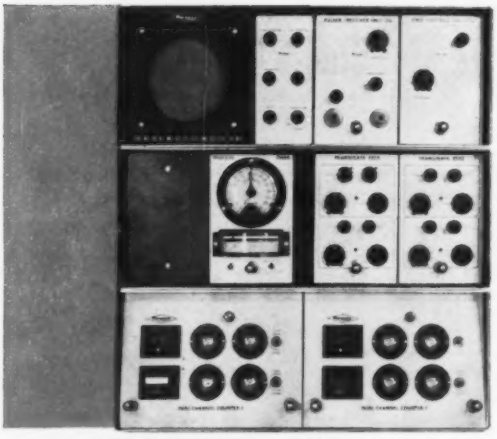


UM 700 Reflectoscope



UM 700 with special function chassis and two transigates



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Metals . . .

readily and becomes severely embrittled. As for columbium and tantalum, they form nonvolatile oxides below 2500° F., but they scale rapidly and become embrittled because of their high affinity for oxygen. At the other end of the corrosion-resistance gamut, molybdenum and rhenium form volatile oxides below 2500° F. and deteriorate catastrophically. Though tungsten oxide is less volatile than molybdenum oxide, it also forms very rapidly. Of the refractory platinum metals, rhodium is the most oxidation resistant and iridium is next. Ruthenium and osmium, both of which are most susceptible to oxidation, bring up the rear. All elements in this group oxidize by volatilization.

The list below compares the oxidation resistance of several refractory metals with a typical stainless steel. Molybdenum, the least resistant to oxidation, is rates as "1".

Molybdenum	1.0
Tantalum	1.4
Columbium	2.3
Hafnium	14.0
Tungsten	14.0
Zirconium	27.0
Titanium	54.0
Chromium	320.0
Type 310 stainless	1600.0

As a general rule, the high-temperature strengths of refractory metals are raised by alloying them with metals which themselves have high melting and recrystallization temperatures. For example, beryllium appears to be an excellent alloying element for improving the properties of molybdenum. (Although the Mo-Be system needs further study, few investigators care to work with beryllium because its oxide is so poisonous when inhaled.) Rhenium (50% by weight) also lowers the transition temperature of molybdenum to as low as −150° C. (−240° F.), but the oxidation resistance of this combination is "miserable", according to Mr. Harwood.

Interestingly, additions of tungsten to molybdenum did not increase the strength properties of molybdenum to any great degree. Further, once the service temperature exceeded the recrystallization temperature in the alloy (and, in fact, any of these refractory-metal alloys), the properties dropped markedly.

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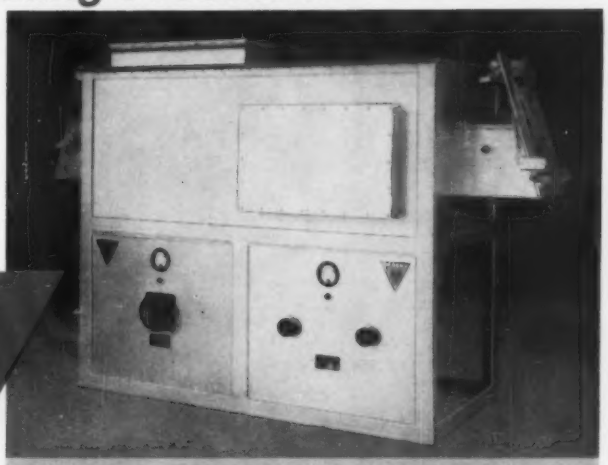
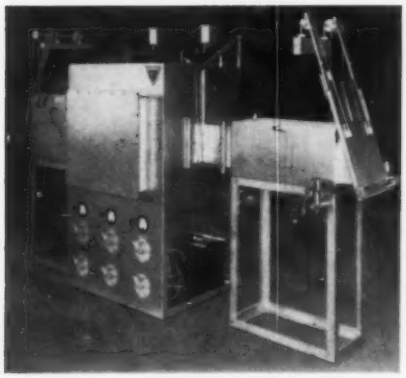
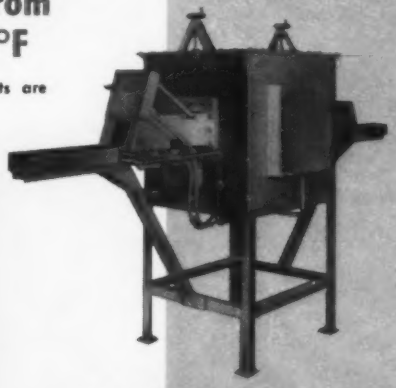


For sintering, brazing, reduction, annealing, metallizing and coating, calcining and experimental work in many other areas.

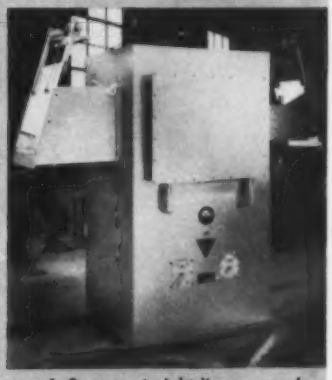
Pereco Series SNX Straight-Line Furnaces are available in any multiple or combination of pre-heat, high temperature, and cooling zones depending upon the requirements of the work to be handled. For example, the unit shown above has *two* immediately adjacent hot zones; one operating at 2900°F while the other operates simultaneously at 2300°F. The high temperature zone is heated with molydisilicide elements and the other with silicon carbide elements. Each has its own power controls. This arrangement, as well as other special operating features — coupled with Pereco proven design "know-how" and high-quality furnace construction — typifies Pereco's capabilities for designing or modifying a straight-line furnace to meet specific needs.



An SNX unit which has a 3-stage "hot" zone separated from both the pre-heat and water-cooled exit zones by interior blast gates, manually operated from outside.



Above: Model SNX-200, for controlled atmosphere work in sintering powdered metals, brazing and other specialized applications in metallurgy or ceramics. Automatic, solenoid-operated flame curtains, with manual or mechanical pusher system optional.



Above: A 3-zone, straight-line, manual pusher-type furnace (SNX-81072) suited to a wide variety of high temperature (maximum 2700° F.) heat treating work. Hot zone incorporates 2 separately controlled banks of silicon carbide heating elements.

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Then, the alloy usually was no stronger than the pure refractory metal.

To sum up the alloying work, titanium and zirconium additions are best to raise the recrystallization temperature and give high strength to molybdenum. Titanium additions increase oxidation resistance, and tungsten and zirconium increase the strength of columbium. (Some columbium alloys have exhibited different properties in vacuum than they have in air or argon.) From a property standpoint, tantalum alloys are competitive with unalloyed tungsten at high temperatures, and tantalum-tungsten alloys appear promising. As for tungsten, thorium oxide (ThO_2) dispersions increase its high-temperature strength, and about 0.50% Cb has a potent effect in increasing the strength of tungsten up to 3000° F.

Hope for Protective Coatings

Considerable research has been done to develop oxidation-resistant coatings for refractory metals. However, no data are available yet on any coating which has exhibited completely satisfactory results, particularly for service above 2500° F. Ceramic, diffusion, and metallic coatings, the three main types under investigation today, are applied by processes such as vapor plating, electroplating, spraying, metal cladding, and diffusion or as slurries or molten metal. To date, silicide coatings appear best for protecting molybdenum against oxidation for short times at elevated temperatures, and zinc coatings have protected columbium up to 2000° F. for short periods. A CbZn coating gives the best results.

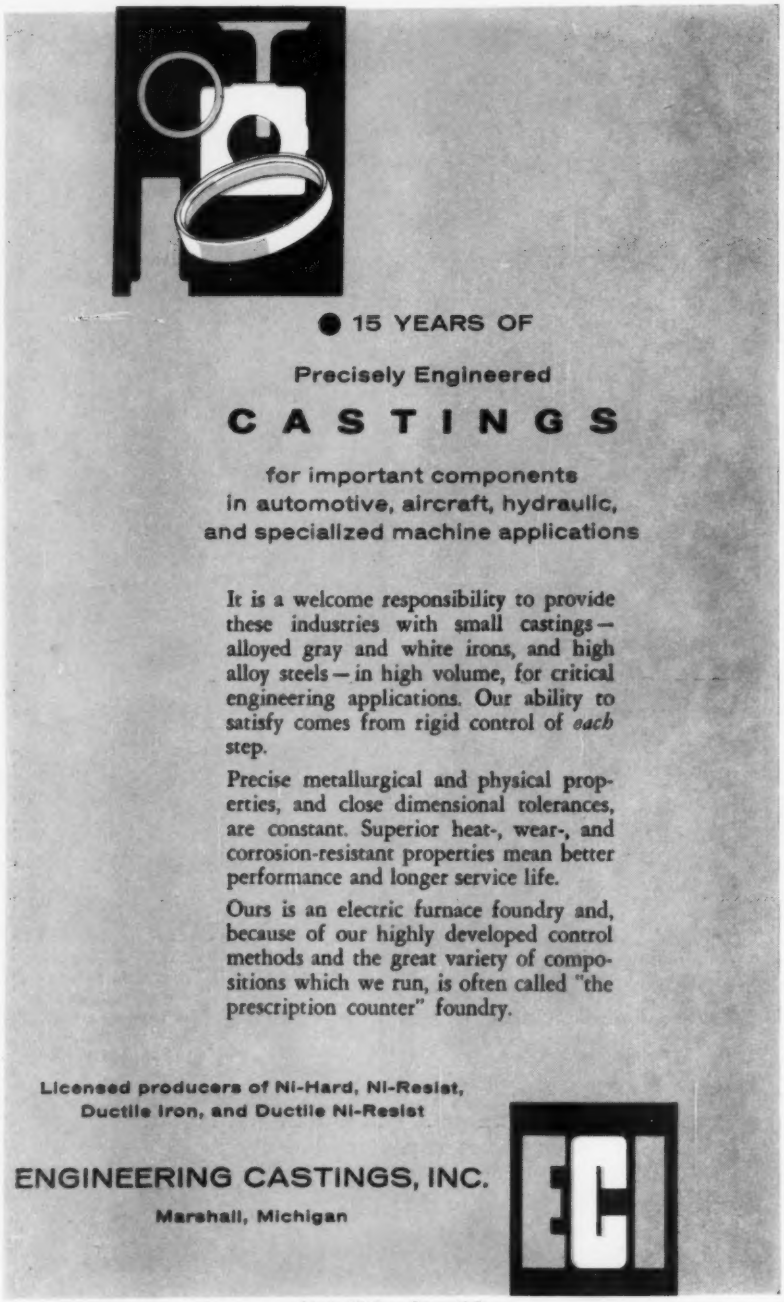
Although many problems are still associated with their use, refractory metals still represent promising materials for high-temperature service in missiles, rockets and satellites.

Magnetic Materials

The second talk of the session, concerning magnetic materials, was given by George W. Weiner of Westinghouse Research Laboratory. He began by saying that the number of ferromagnetic compounds available is limitless, but only a few were of commercial use at present.

In ferromagnetic materials, two important properties to be studied are "magnetostriction" and "magnetocrystalline anistropy". Magnetostriction is defined as the change in length of a material when it is magnetized. (Nickel shortens when it is magnetized, but iron lengthens.) Magnetocrystalline anistropy (random orientation of magnetized crystals), a characteristic common to most materials, can be minimized by adjusting the crystal orientation. Two factors determine the ability to move crystal domain walls: the amount of impurities present (primarily precipitated impurities, rather than those in solid solution), and the state of strain in the magnetic material.

Dr. Weiner next discussed several magnetic materials including cubic-oriented iron, an iron-cobalt-vanadium alloy (Supermendur) which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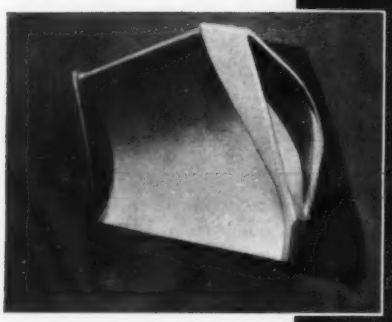

Casting of nozzle guide vane for turbo-jet engine

Radiograph shows casting sound and up to its job

Nozzle guide vanes in turbo-jet engines must withstand fiery blasts — dependably. Austenal Company, division of Howe Sound Company, checks the soundness of each cast vane with radiography

Cobalt base or nickel base high-temperature alloys are required in order to withstand these terrific temperatures. Investment castings are specified because of the alloys that must be used and because the vanes would be almost impossible to forge, machine, or otherwise fabricate, at the cost level of investment castings.

Austenal Company, division of Howe Sound Company, casts these blades by the "lost wax" method. Each one is then radiographed to make sure that no hidden flaw lurks within that could cause failure.

Makers of quality castings, small and large, find radiography invaluable in making sure that only high-quality work is delivered. It is a way reputations are built and new business won.

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could be magnetically saturated to 24,000 gauss, and ferrites*.

The latter are soft magnetic materials with low coercive forces. Thin films of ferrites are being studied with considerable interest because of their effects on magnetic changes. So far, researchers have established that they are less temperature-dependent as far as their use is concerned than are other soft magnetic materials.

*Note to metallurgists: A "ferrite" in this context is a nonmetallic oxide with extremely high resistance, not alpha iron.

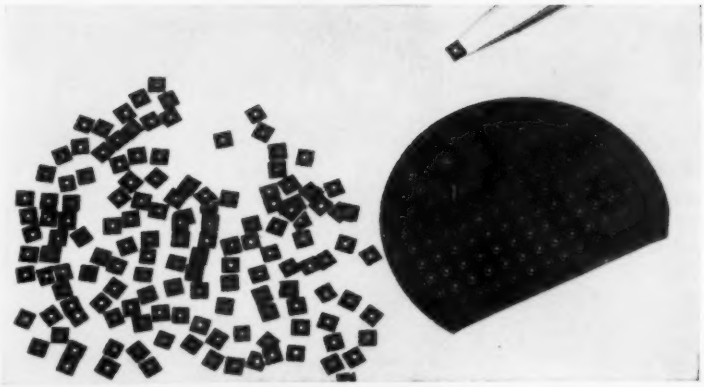


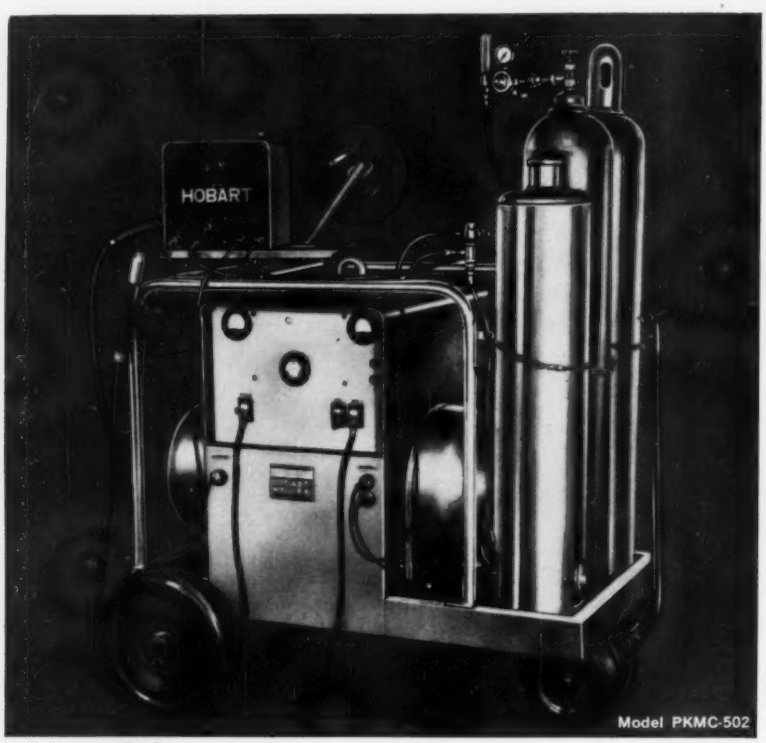
Fig. 2—"Wafer" of Semiconducting Material Partially Cut Into Transistors at Fairchild Semiconductor Corp. Though transistor-grade silicon (or germanium) costs up to $500 per lb., very small amounts are used in each transistor

Concerning permanent magnetic materials, researchers aim for single-crystal domains because they are extremely difficult to demagnetize. For example, the properties of Alnico, a widely used material for permanent magnets, are related to the fact that the precipitate is essentially a single domain. In line with this, iron-cobalt powders prepared with single domains have properties approaching those of Alnico. Also, a considerable amount of research is being done on the use of iron oxides as permanent magnets, and the results appear promising.

Superconductors, materials with zero resistance, are also attracting attention. Columbium-tin (Cb_3Sn) is a superconducting material which, according to Dr. Weiner, may be the potential magnetic material of the future. When current is applied to this material, it will continue to circulate without losing strength, traveling indefinitely once it is started. Furthermore, superconductivity in this material can be maintained up to 88,000 gauss, four times the saturation of iron.

Transistor Materials

During the third talk of the session, C. Sheldon Roberts of Teledyne, Inc., in discussing new trends in solid-state electronic materials, stated, "There is real need for a



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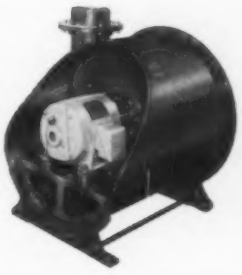

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Circle 1152 on Page 48-B

Metals . . .

material that will provide a reduction in cost, coupled with an increase in reliability. Reduction in weight and in power requirements to operate electronics systems are also factors which need further study."

Silicon and germanium, the most familiar semiconductor materials, are still expensive, but the cost has dropped considerably over what it was several years ago. Today these materials cost around $100 to $300 per lb. (in single crystals—from $400 to $500 per lb.); however, very small volumes of these materials are used per unit.

As the first step in making a transistor, a large single crystal is grown. After several purifications (by zone refinement), the crystals are cut with a diamond saw into thin wafers. Figure 2 illustrates a wafer partially sectioned into individual transistors. In the completed transistor, leads are attached to the small dot (called the "emitter") in the center. The transistor die is then mounted and sealed into a transistor "can".

In advancing the state of the art in transistor manufacture, Dr. Roberts concluded by suggesting that work should be done in devising new methods of shaping crystals and new approaches to "doping" (adding controlled amounts of impurities).

Testing With Photoelastic Coats

Digest of "Photoelastic-Coating Technique for Determining Stress Distribution in Welded Structures", by F. Zandman, *Welding Research Supplement*, May 1960, p. 191s-198s.

WHEN STRESSED, transparent plastics become doubly refracting (birefringent). Thus, when a beam of polarized light is passed through a transparent plastic model under stress, a colored picture forms from which the stress distribution can be determined. This technique is called photoelasticity.

The photoelastic-coating technique is a variation of this method; the actual structure to be tested is coated with a photoelastic plastic. (This technique is basically different from conventional photoelastic meth-

METALGRAMS

. . . news of "Electromet" ferroalloys and metals

UNION CARBIDE METALS

SEPTEMBER 1961

CHARACTERIZATION OF FERROALLOYS -- To provide more complete information to steelmakers, UCM recently published data on the occurrence of hydrogen and non-metallic inclusions in alloy additives. Laboratory and field studies made over a period of many years demonstrate that these raw materials, which are used to control the composition of steel, exert a negligible influence, if any, on the gas content and inclusions present in steel. For details, write for the article, "Alloy Quality Versus Steel Quality," in the Summer 1961 issue of UNION CARBIDE METALS REVIEW.

* * *

TUNGSTEN -- HELPS ALLOYS RESIST HEAT -- Because of tungsten, high-speed steel and non-ferrous tools have cutting edges that stay hard under extreme friction and high temperatures. Hot-work tool steels punch, shear, or form metals at high temperatures without softening. Iron- and cobalt-base turbine blades, afterburners, and tailpipes resist erosion and heat from fast-moving hot gases. Union Carbide Metals supplies ferrotungsten, self-reducing tungsten, scheelite, and tungsten metal powder for such additions. Your UCM representative can give you further information. Also, ask for the article, "The Elements That Surround Us: Tungsten," in the Winter 1960 issue of UNION CARBIDE METALS REVIEW.

* * *

MANGANESE IN ALUMINUM -- In binary alloys, manganese improves the strength of aluminum by 20 per cent with no sacrifice in corrosion resistance. Thus, 3000 series alloys (containing 1.25 per cent manganese) are good general-purpose alloys for storage tanks, piping, furniture, TV antennas, awnings and siding, and chemical equipment. Manganese is also added to 2000, 5000, and 6000 series alloys to improve corrosion resistance. UCM offers low-iron ferromanganese and "Elmang" electrolytic manganese for such additions. More information can be obtained by writing for the article, "Manganese Puts Muscle in Aluminum," in the Winter 1961 issue of UNION CARBIDE METALS REVIEW.

* * *

SALUTE TO STEEL FOUNDRIES -- In 1861, the first steel castings made in the United States were poured in Buffalo, N. Y. They were railroad castings, still an important use of steel castings today. This year, steel foundries observe their first 100 years of serving the railroad, earth-moving and construction equipment, rolling mill, mining equipment, military, oil and gas, automotive, and other industries. Some 275 foundries in the U. S. and Canada can pour about 2 1/2 million tons per year for these uses. Union Carbide Metals wishes the steel foundry industry continued growth and success and looks forward to serving its ferroalloy needs in the future. Your UCM representative is always at your service.

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Circle 1153 on Page 48-B

Photoelastic Coats . . .

ods where a plastic model of the structure is strained and measured. It differs also from the strain-gage method in that the strain gages measure the strain only in the area where the gages are located.

If a reflective surface is provided, birefringence can be observed and measured with a reflection polariscope. The black, isoclinic fringes are the loci of points where the directions of the principal stresses are constant and are the same as the directions of the axis of polarization. They become visible when the axis of the polarizer and analyzer are crossed. Simultaneous rotation of these elements through 90° reveals the directions of the principal stresses at each point of the structure. Two families of isostatics, stress trajectories, can be plotted from the isoclinic fringes. When two quarter wave plates are used, the plane polarized light is transformed into circular polarization. The colored fringes (isochromatic fringes) which are visible are loci of points where the principal stress difference is constant.

There are four basic methods for measuring the fringe value with polarized light. In order of increasing accuracy they are: *(a)* comparison with a color-versus-strain chart obtained by calibration; *(b)* counting the number of "tint-of-passage" fringes from an area of zero principal strain. (The first "tint-of-passage" fringe corresponds to a strain difference, f, whose value in microinches is calibrated according to type and thickness of the plastic); *(c)* the use of an "optical compensator," and *(d)* conversion of colors to photoelectric currents which are measured by means of calibrated photometers.

While thicker plastic coatings result in more fringes, the practical maximum is 0.120 in. which will provide a strain sensitivity of ±10 micro-in. per in. when a compensator is used. However, the accuracy of the measurement of the plastic thickness must be maintained to assure this strain sensitivity.

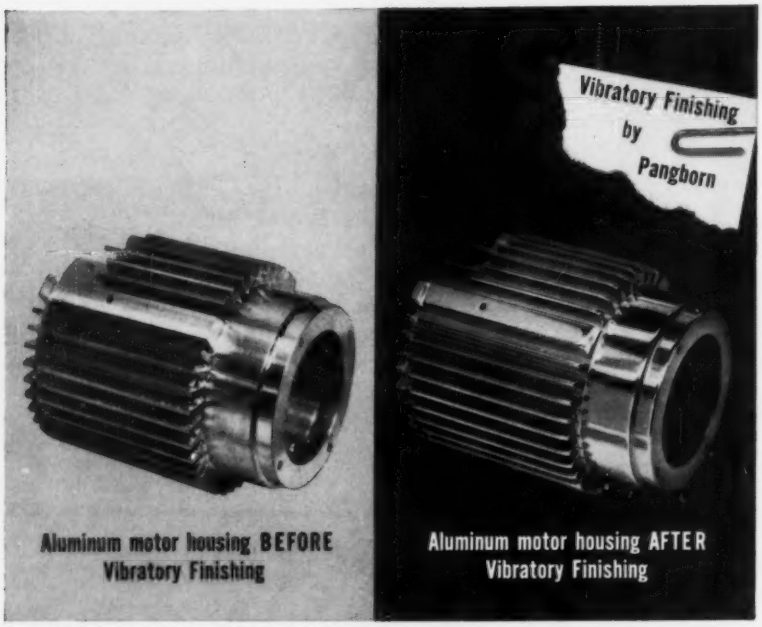
The photoelastic coating can be applied by brushing liquid material or bonding sheet material, both of which are polymerized by heating after application. The maximum strain which can be measured varies with the plastic between 3 and 50%; however, the 3% material is generally used on metals.

Advantages of the photoelastic coating method include: *(a)* virtually a zero gage length is distributed continuously over the surface; *(b)* photography can be used while the specimen is loaded dynamically; *(c)* accuracy is good; *(d)* data equal to that obtained from a strain-gage rosette are obtained.

Its limitations include: *(a)* method is limited to surfaces which can be illuminated; *(b)* temperature must be controlled between −40 and +95° F. and should be held constant; and *(c)* only surface strains are measured.

Application to Welded Structures

Photoelastic methods can be used to determine residual stresses resulting from welding, internal stresses usually being measured by relaxation methods. In one example, the stresses in a mild steel rod, 4 ft. in diameter, protected with a stainless



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Circle 1154 on Page 48-B

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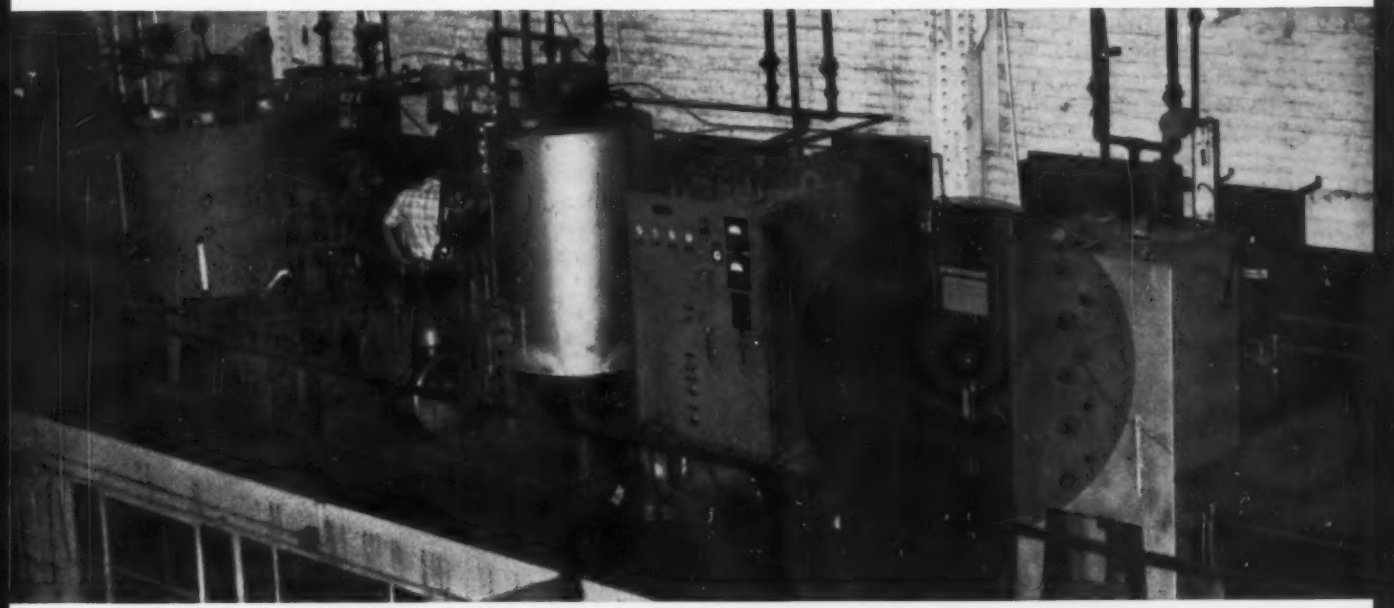

Typical installation shows M-S-A LIRA Analyzer calibrated for suitable dew point ranges to determine carbon potential of the furnace atmosphere.

Heating metals like steel, copper, brass, etc., generally makes them chemically active with the atmosphere in the furnace.

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Circle 1155 on Page 48-B

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Photoelastic Coats . . .

steel weld 1 in. thick over its surface, have been determined. Sections cut from the rod were coated with plastic, and the weld material machined away in shallow cuts. Magnitudes of principal stresses were measured with small field and oblique incidence meters. Directions of these stresses were determined with a large field meter.

Stress distributions were also measured in welded aluminum plates and a tube welded to a flange. Stress relaxation was again achieved by machining. For the plates, cuts were made to first remove the stresses due to manufacture and then those due to welding.

The photoelastic method has also been used to determine stresses in welded structures subjected to external loads. A spot welded pressure vessel was loaded hydrostatically (but with oil, not water) after sheet plastic 0.04 in. thick was applied to the external surface. Using large and small field meters, stress concentration factors were found for several spot weld spacings.

While some of the data obtained by the photoelastic coating technique could have been obtained by other methods, such as strain gages, the former method is considered advantageous especially where a large area must be surveyed. In this system, the major advantage lies in its ability to observe the strain distribution directly on the working part.

R. F. HARTMANN

Bearings for High-Temperature Use

Digest of "Recent High-Temperature Bearing Developments", by John H. Johnson. Paper (Preprint 176A) presented at the S.A.E. National Aeronautic Meeting, April 1960, New York.

RECENT APPLICATIONS of rolling contact bearings at high speeds and high temperatures in synthetic lubricants have required bearing tests in environments specifically simulating those of actual service. These tests, conducted in Oronite 8200 hydraulic fluid at 450° F., were designed to evaluate the expected decrease from AFBMA calculated ratings. The test bearings were MRC - R - 110 - KD roller bearings made from M50 tool steel which was vacuum melted (consumable electrode). Retainers were of silver-plated silicon-iron bronze. The bearings of Grade RBEC-5 with 0.0010 to 0.0014-in. radial clearance were fully submerged in Oronite 8200 hydraulic fluid flowing at 0.8 gal. per min. for each four-bearing spindle. At 600 rpm. with 1625 lb. per bearing, the calculated B-10 life was 500 hr. with no allowance for the special environment.

During tests, a pressurized blanket of N_2 was maintained to prevent oxidation of the silicate ester type fluid. Extensive tests during and after running showed no harmful decomposition of the Oronite fluid, though slight oxidation was evident and the amine antioxidant additive was rapidly depleted.

In Phase I, eight bearings completed 500 hr. without failure. In Phase IIA the test of 20 bearings was discontinued because of early failures at the extreme ends of the contact area which indicated severe stress concentration. In Phase IIB new rolls were assembled with unfailed raceways from Phase IIA (inner rings reground). Eight such bearings were tested with 14 new bearings. The resulting life was still only 10% of the estimated life, and the failures were of various types.

Examination of the data showed that all but one failure in Phase IIB had occurred in an outboard test position, and that misalignment due to excessive deflection of the housings was the principal cause of failure. However, the "new" bearings in Phase IIA showed predominantly roll failures with poorer life than the "old" bearings assembled with used races and new rolls. This difference of failure characteristics apparently occurred because the rollers in the "new" and "old" bearings were from different heats of material.

It was concluded that (for the conditions of load and speed used in these tests) there is no evidence to warrant derating of AFBMA predicted lives for roller bearings operated in Oronite 8200 hydraulic fluid at 450° F. when the fluid is properly protected from oxidation and the bearings are mounted to prevent excessive misalignment.

W. E. LITTMANN

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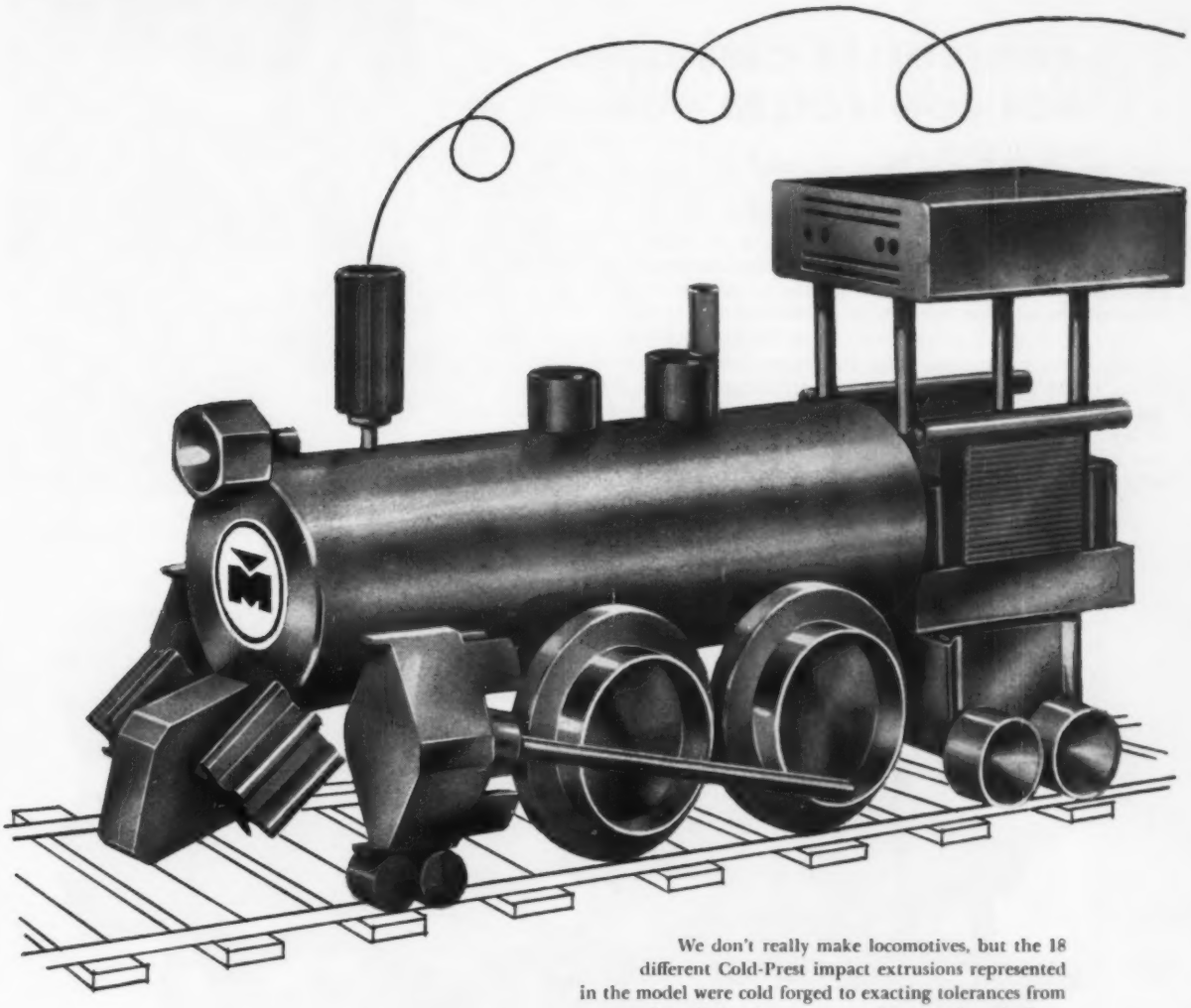

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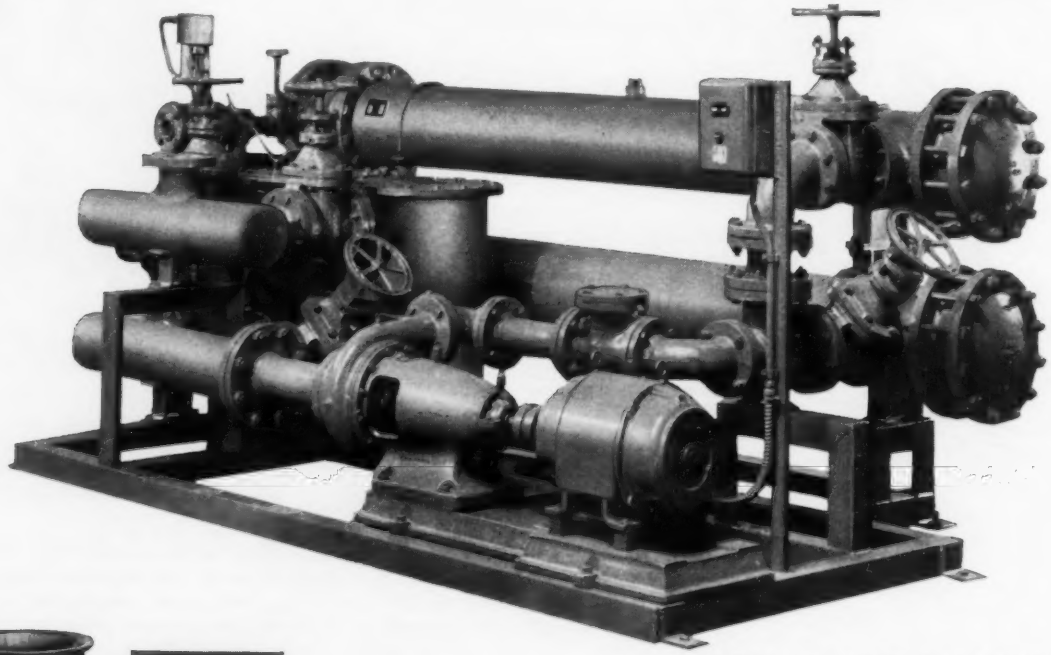

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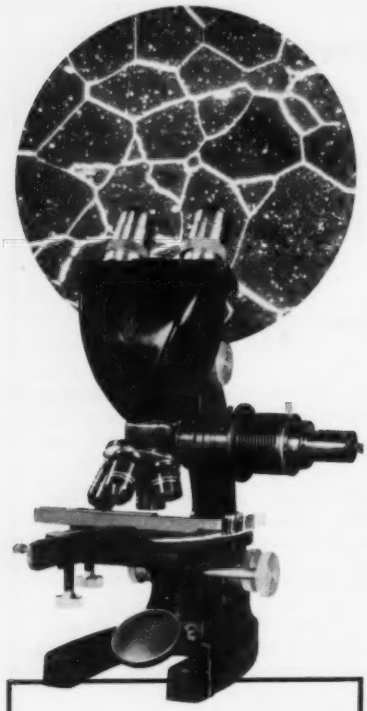

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Circle 1166 on Page 48-B

"Hyper-Hot Working" of Aluminum Alloys

Digest of "Improvement in the Anodizing Properties and Corrosion Resistance of Aluminum Alloys by Hyper-Hotworking", by J. Hérenguel and P. LeLong, *Metal Finishing Journal*, July-August 1959, p. 275-282.

IT IS WELL KNOWN that differences in flow speeds associated with the extrusion process give rise to certain textures in the billet (or slug) and in the extruded bar. Subsequent heating results in zones of special recrystallization, a periphery of coarse grains. These zones involve a considerable re-organization of the heterogeneous "as-cast" structure into a fine, uniformly dispersed pattern which is sometimes responsible for peculiar surface effects revealed by anodizing. This mechanism has been called "hyper-hot working."

These investigations were made on an aluminum alloy containing 1.0% Fe and 0.003% Si. In this alloy, almost all of the iron is present as a second phase so long as heat treatment alone is applied. For the experimental work, extrusion billets – 4 in. diameter by 10 in. long – were cast and relatively slow-cooled to produce a fairly coarse pattern of minor segregation. Changes in this pattern caused by hot working could be easily analyzed.

The billets were extruded at 400° C. (750° F.) through a straight die, and at a reduction ratio of 25:1. Only four-fifths of the billet was extruded, the remainder being recovered for structural examination. Several samples of the extruded bar were observed after they were rolled.

When the portion of the billet remaining in the container after extrusion was examined, four zones were revealed:

1. A central zone with an elongated fibrous appearance.
2. An intermediate zone, retaining practically the as-cast structure.
3. An outer zone of intense shearing between zones 2 and 4.
4. A dead corner zone, with structure practically as-cast.

Zones 2 and 4 retain an as-cast structure, and this pattern is progressively elongated on either side towards zones 1 and 3. On passing through the die, it undergoes simple elongation with fragmentation and alignment of phases which are not in solution.

The central zone is extruded more rapidly than the rest of the billet as it elongates. There is a slight shearing relative to zone 2. Its structure is similar to the as-cast billet; however, the $FeAl_3$ needles are subdivided into small particles.

The pattern of heterogeneity in the outer sheared zone is completely different than that in the central zone. Though the $FeAl_3$ constituent is finely divided, a slight alignment is evident in some areas. This is a result of an incomplete redistribution of the coarser as-cast phases. The unextruded billet structure contains less evidence of alignment, and the structure becomes finer closer to the die end.

The structure of the extruded bar changes progressively along its length. Nevertheless, a hyper-hot worked zone of varying thickness exists along most of its length. The uniform dispersion of very fine $FeAl_3$ particles suggests that this phase was rendered "hypersoluble" during shearing, and then reprecipitated after extrusion. The heterogeneous as-cast structure appears to change to an ultrafine and regularly dispersed precipitation structure.

Immediately below the sheared zone the structure was similar to the as-cast structure except for geometric elongation. While this structure was finer and more uniform in the "last extruded" end of the bar, it did not attain the uniformity and degree of dispersion of the outer sheared zone.

"Reticulage" is a geometric pattern on the surface of anodized aluminum alloys; it is associated with defects in the transparency of the alumina film. These defects are related to the pattern of minor segregation geometrically deformed during working. Careful choice of solidification conditions and refining additions have been used to control reticulage. But with "hyper-hot working" the normally insoluble phases can be divided and dispersed, and reticulage is effectively reduced.

Certain additions in the aluminum (iron and nickel, for example) lead to the formation of insoluble phases, and to the increase in the corrosion resistance of the alloy to water above 100° C. (212° F.). It has been suggested that these insoluble phases

protect the surrounding solid solution over a limited area. "Hyper-hot working" should, therefore, increase the effectiveness of these phases through improved dispersion.

Samples of the 1% Fe aluminum alloy described previously were exposed to degassed ion-exchange water (pH = 6.3) for 10 hr. at 360° C. (680° F.) along with control samples taken from the same billet, but fabricated by multidirectional rolling. These experiments revealed that the depth of penetration was related to the distribution of $FeAl_3$, and that the hyper-hot working metal showed very good resistance to corrosion.

R. F. HARTMANN

Fretting Corrosion

Digest of "Fretting Corrosion of Metals", by R. T. Allsop, *Metallurgia*, August 1959, p. 39-43; September 1959, p. 87-92.

FRETTING CORROSION may be defined as a form of concentrated damage initiated by metal transfer and wear between two contacting surfaces whenever the rubbing conditions favor trapping of wear particles. Typical examples are found in rotating shafts with press-fit members, and the interfaces of laminated springs, bearings and bolted or riveted joints. Various theories of the mechanism have been advanced, but general agreement on a comprehensive theory has been hindered by the lack of quantitative data. Several workers have suggested mechanisms, however.

For example, Uhlig considers that fretting corrosion involves two factors, one being chemical, the other mechanical. The chemical factor arises from the continuing removal and re-formation of the oxide film on contacting asperities. The mechanical component is due to the interaction of the projections, resulting in loose metallic particles which eventually oxidize. He developed a mathematical relationship between damage (weight loss) and such variables as load, frequency and slip. In subsequent experiments, the observed damage was in fair agreement with the calculated values.

Wright based his theory on the view that the process is one of wear accelerated by the presence of oxy-

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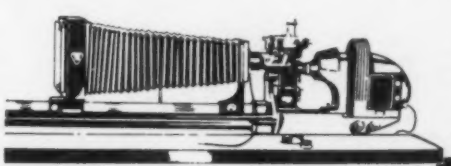

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Circle 1167 on Page 48 B

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Circle 1169 on Page 48-B

Fretting Corrosion . . .

gen, which prevents continuous metal transfer and forms abrasive oxide. From electron microscope studies, he concluded that the initial damage is due mainly to the plowing action of metal fragments, which subsequently oxidize. With the harder materials, the particles are smaller and the oxidation more rapid. The debris, being essentially confined, builds up until intermetallic contact is prevented, and the actual slip reduced. Thus, the process becomes one of abrasion by oxide particles. The damage rate decreases with time to a steady value when the rate of debris formation equals the rate at which it escapes. Supporting evidence for Wright's theory was provided by electrical resistance measurements.

Waterhouse has proposed that the chemical process, as suggested by Uhlig, is responsible for most of the damage in air. This theory is inconsistent with the bulk of the available data, and ignores the close relationship shown to exist between the chemical action and mechanical wear.

The theory put forward by Feng and Rightmire is similar to that of Wright. Initially, the oxide film is believed to prevent metal transfer, and loose wear particles are formed. However, the thin oxide film, which forms on the freshly exposed surfaces, is unable to prevent metal transfer which then takes over. As transfer continues, the number of asperities increases, the individual load and plastic deformation decreases, and loose particle production increases. The accumulation of debris then changes the process to one of abrasion, resulting in an increase in the damage rate. Finally, the slip decreases and the damage rate levels off. Evidence in support of this mechanism has been presented recently by its originators in a study of the initial stages of fretting of steels. The fretting damage-number of oscillations curve did not increase monotonically, but rose rapidly to a plateau and then continued at a decreasing rate.

The author concludes that both the corrosion theory and the accelerated wear concept can probably be applied to the fretting mechanism. But the part played by the

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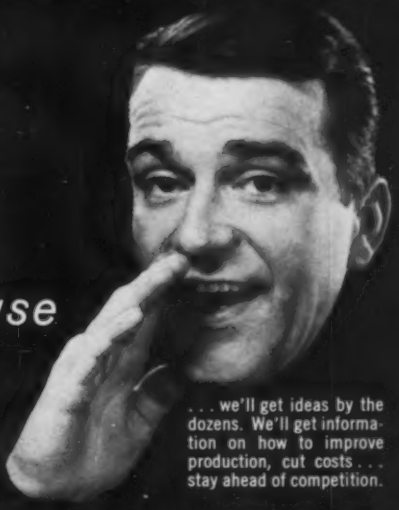

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Circle 1170 on Page 48-S

Fretting Corrosion . .

former process is so small that it can be neglected.

Fretting Corrosion and Fatigue

Fretting corrosion may reduce the fatigue strength of a component in two ways: *(a)* slip between the contacting surfaces will constitute a localized fatigue system that may develop minute cracks, and *(b)* the general roughening of the surface may give rise to stress raisers.

Waterhouse carefully examined fretted surfaces (by magnetic powder methods) and found no minute surface cracks. Surface roughness measurements showed two types of damage – shallow depressions and small deep holes. He suggested that the former resulted when the debris was able to escape from between the surfaces, and the latter when it was completely entrapped. Waterhouse concluded that the stress-raising effect of the latter would be likely to reduce the fatigue resistance.

A quantitative evaluation of the effect was made by Warlow-Davies, who pre-fretted steel specimens, and then subjected them to fatigue tests. The fatigue strength of mild steel was reduced by about 13%, and of alloy steel by about 18%. In contrast, failure has been reported at points away from areas extensively damaged by fretting in some tests at the National Physical Laboratory.

Another factor influencing the fatigue resistance is the clamping pressure between the surfaces. Peterson and Wahl showed that increasing the press-fit pressure of a fitted member on a steel shaft reduced the fatigue strength initially, but had no further effect beyond 5000 to 10,000 psi. Similar results were obtained for a titanium alloy by Liu, Corten and Sinclair. Horger and Niefert noted that the more highly stressed shrunk-on wheels reduced the fatigue strength of railway axles more than pressed-on wheels. Investigations to date, however, have not differentiated clearly between the effects of fretting damage and clamping load.

Influence of Various Factors

Fretting damage increases with the duration of the test in air. According to Wright, the relationship

is linear, starting from the origin. Feng and Uhlig, however, found a "run-in" period with a higher damage rate before the relationship became linear. Close examination of the initial stages by Feng and Rightmire, as mentioned previously, showed the existence of a plateau.

The effect of atmospheres other than air has been investigated by Feng and co-workers. In nitrogen, they found that the damage was much less than in air, whereas in dry CO_2, although the plateau period was extended, the total damage eventually approximated that in air. It is suggested that the behavior beyond the plateau is determined by the ability of the atmosphere to interfere with metal transfer. Nitrogen forms only a slight absorbed film, whereas with CO_2 the amount of gas adsorbed is sufficient to permit the generation of the loose particles which allow fretting to continue by abrasion. In nitrogen, damage may never develop beyond the plateau stage.

Humidity appears to reduce the damage for steel and chromium (both against steel) in air – up to about 50% humidity. Beyond this value, the data are not consistent. Wright suggested that a water film produced on the metal and oxide surfaces acted as a lubricant and helped to remove debris. The fact that damage increases sharply at the freezing point of water supports this view. Humidity is reported to have little effect in a nitrogen atmosphere. The relationship between normal load and fretting damage (providing the slip is kept constant) is almost linear, the damage increasing with the load. If, however, the slip is not adjusted, it will decrease as the load increases, with the result that damage will rise to a maximum and then decrease to zero when relative movement is eliminated.

Some difference of opinion exists with regard to the effect of frequency. Several authors have claimed that there is no effect over quite a wide range of frequencies. Feng and Uhlig have shown for mild steel in air that damage decreases as frequency increases up to about 1000 cpm., and then levels off. These results, however, apply to relatively large amounts of slip, and are complicated by the temperature variations produced. An attempt was made to correct for the latter.

The effect of increasing the amplitude of relative movement is to increase the damage. Some slip is essential if damage is to occur, and beyond that point the relationship is roughly linear. Relative movement, of course, does not include the elastic strain in the two surfaces.

The effect of temperature is not clearly established. For mild steel in air, damage decreases from 0 to 50° C. (32 to 120° F.) and then levels off. Below the freezing point of water, damage apparently depends upon the duration of the test. For short tests there is no effect, but for longer tests the damage increases linearly as the temperature is reduced.

When steel is fretted in moist air, the debris is alpha-Fe_2O_3. At low

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Circle 1171 on Page 48-E

"We had 18-20 hours downtime every time we changed heats. With strip, we just hook on from heat to heat. No downtime."

"With strip we use smaller blanks to produce the same part."

"By using strip we save downtime, die repairs."

"Rejects have dropped from about 8% to less than 1%."

"We found we couldn't afford the low cost of sheet."

Read why Target Stamped Products, Inc., Kinsman, Ohio, switched from strip to sheet—and then back to strip. Comments are Harvey Haynam's, Target's president:

"We thought we'd give sheet a try back in 1958. The low cost looked too good to pass up. Today, you'd have a hard time finding a piece of cold rolled sheet around the shop.

"We were absorbing 18-20 hours of downtime every time we changed heats. With strip, we just hook on from heat to heat. The characteristics are the same from heat to heat and coil to coil. We don't waste time adjusting our dies.

"Strip saves us metal. We can use smaller blanks to produce the same part. I'd say we save from 1/16" to 3/32" of metal per part. That's a lot of steel when you're turning out 25-30 million parts a year.

"We don't have gauge problems now. The strip we buy is always rolled within our working tolerance. We work to a plus or minus .0025 inches.

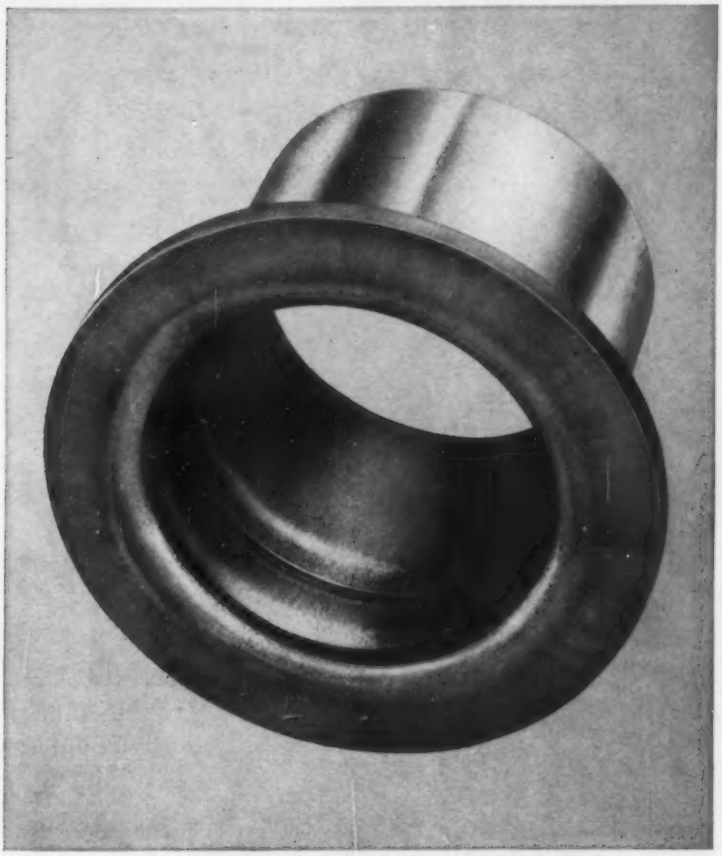
"So far, strip hasn't given us lamination troubles. It doesn't take much lamination to give you big trouble in a deep drawing operation. When the metal separates, part may stick to the punch while part stays in the cavity. As another blank transfers to the same station, there's a double smash and the die is ruined. That hasn't happened with strip. Saves a lot of downtime and die repair.

"Strip takes a deep draw without thinning out on you. Its uniform temper pays off when you're turning out Silent Blocks where both the ID and OD have to be right or the part's a reject.

"All in all our rejects have dropped from about 8% to less than 1% since we switched back to strip.

This mark tells you a product is made of modern, dependable Steel.

Outer metal bushing of a Silent Block. Target Stamped Products turns out millions of these each year for the auto industry. Silent Blocks are used in the suspension systems of all American cars—about eight to a car. To produce the piece, Target must work to a plus or minus .0025" tolerance or the Silent Block won't work. When Target switched back to strip, their rejects dropped from about 8% to less than 1%.



"You can have all the automation in the world, but if you're using the wrong steel, it just nickels and dimes you to death. With strip our machines keep working; we need less supervision, less tool repair. Our trim is small and our percentage of rejects is the smallest we've ever known. We found out we couldn't afford the low cost of sheet. That's why we're back with strip."

The switch is back to strip

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Strip is not sold on an as-rolled basis. What you buy is a specific chemistry, temper, dimension, edge and finish to precisely meet your fabricating and end-use requirements.

American Steel and Wire has over 12,000 mill practices in available strip specifications. Many of your processing steps may actually be eliminated by using cold rolled strip.

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Circle 1189 on Page 48-B

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Circle 1172 on Page 48-B

Fretting Corrosion . . .

humidities, some alpha-Fe may be present, the amount decreasing as the hardness of the steel increases. If the supply of oxygen is restricted, both Fe_3O_4 and alpha-Fe_2O_3 may be present, the latter appearing after about 1,000,000 oscillations. In nitrogen, the debris was found to be alpha-Fe.

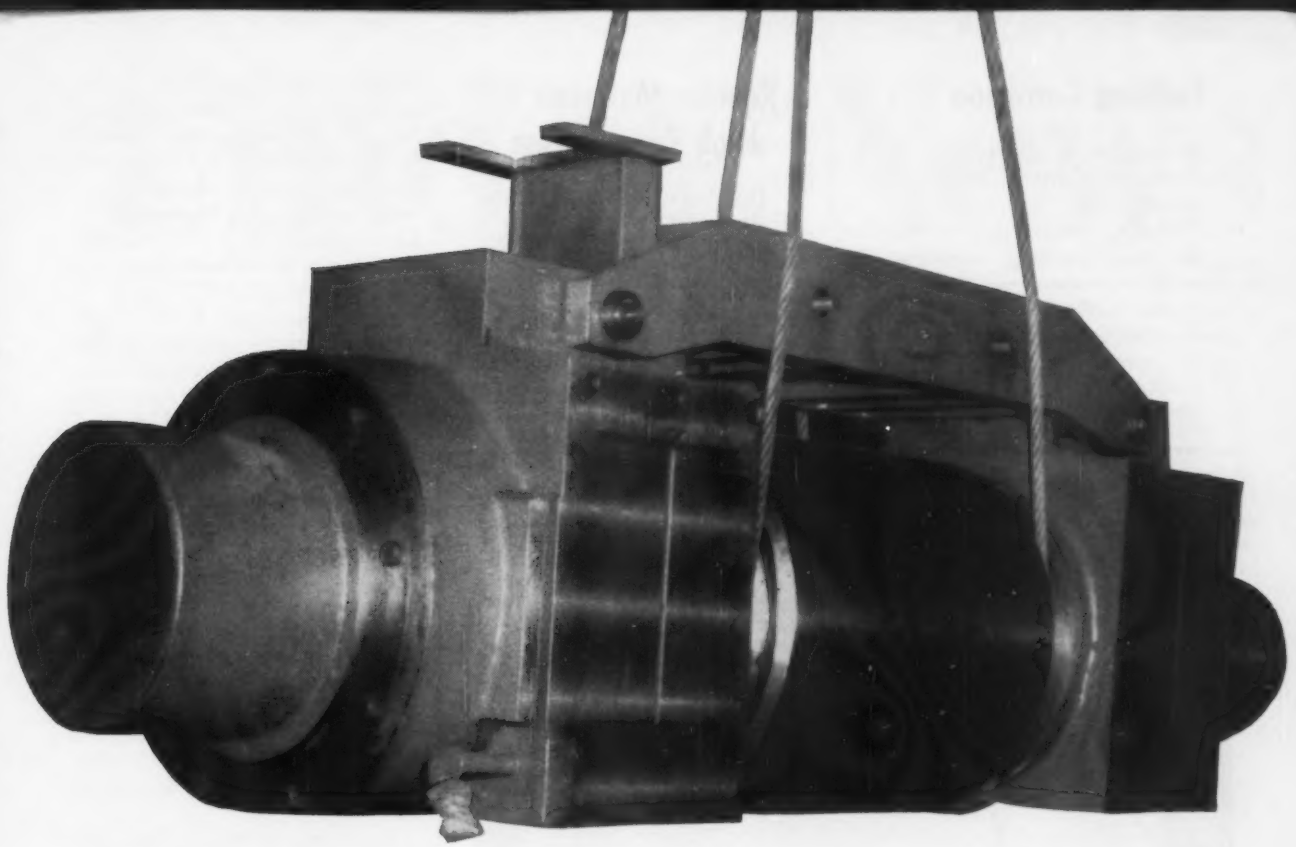
Prevention of Fretting Corrosion

Essentially, individual cases of fretting should be considered on their merits. The most obvious method is to eliminate the vibratory forces, but this is generally impracticable. It is often possible, however, to reduce or eliminate relative movement. Increasing the normal load may prove satisfactory in some instances. In others, plating may increase the coefficient of friction and give the desired result. Silver, gold, tin and copper have been successfully plated for this purpose. It should be noted that if slip is not eliminated, damage will still occur.

Another possible method is to prevent or restrict access of oxygen to the contacting surfaces. A convenient and practicable procedure is to introduce (between the surfaces) a liquid in which oxygen has a low solubility. Wright has shown that paraffin will reduce damage by a factor of about 200. Dried normal hexane, which possesses a higher oxygen solubility, gives a much smaller reduction.

Various types of lubricant have also proved effective in reducing damage under certain conditions. The beneficial effects of hydrocarbon fluids have been attributed to their ability to separate the surfaces, but an alternative explanation is based on their ability to exclude oxygen. Further improvement has been reported for steel by phosphating the surfaces; the oil film in such cases is more stable.

Solid lubricants, both metallic and nonmetallic, have been used, and considerable success was reported for molybdenum disulphide baked on to steel. This coating, however, may break down under high loads, and furthermore it involves heating to 350° C. (660° F.). A thin coating of a metal with low shear strength on a hard backing will reduce fretting damage; a typi-



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Circle 1173 on Page 48-B

Fretting Corrosion . . .

cal example is lead plating, which eliminated fretting in laboratory experiments.

Finally, in selecting a material for use under fretting conditions, it would be remembered that increasing the hardness of steel acts to reduce fretting damage. If necessary, this may be achieved by a surface treatment such as carburizing or nitriding. R. C. A. THURSTON

Reactor Materials at High Temperature

Digest of "Improvement of the High-Temperature Strength Properties of Reactor Materials After Fabrication", by R. W. Swindeman and D. A. Douglas, *Journal of Nuclear Materials*, Vol. 1, 1959, p. 49-57.

THE SHEET AND TUBE MATERIALS used in nuclear reactors must have good high-temperature strength as well as good formability. Unfortunately, however, materials possessing good high-temperature strength are usually difficult to fabricate into the complex shapes needed. As a result, past practice has been to select a material which was borderline with respect to fabrication, and was barely adequate with respect to strength. Since such a compromise has not been very satisfactory, this investigation was undertaken to determine whether or not there were any treatments which would improve the strength of the more fabricable materials after forming.

Three possibilities were covered:

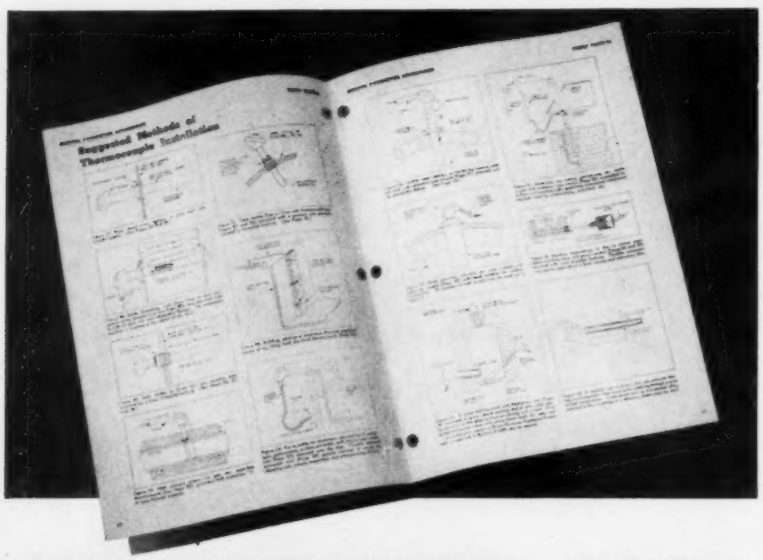
1. Heat treatment to produce optimum grain size and aging properties.
2. The addition of an alloying element such as carbon by carburizing.
3. Selection and control of an environment which would enhance the high-temperature properties.

Four metals were investigated: nickel, Inconel, Hastelloy B, and INOR-8 (7 Cr, 4.85 Fe, 15.8 Mo, 0.02 C, 0.34 Mn, 0.32 Si, 0.02 B, bal. Ni).

Specimens of Inconel were heat treated to produce coarse and fine-grained structures. Annealing for 1 hr. at 1650° F. produced the fine-grained structure, and annealing for 1 hr. at 2050° F. produced the coarse-grained structure.

Stress-rupture tests were conducted at 1300, 1500, and 1650° F. Fine-grained material was superior at 1300° F., the coarse-grained was superior at 1600° F., and they were practically equal at 1500° F.

The effects of solution annealing and aging were also investigated. Specimens of Hastelloy B (an age-hardenable material) were solution annealed at 2050° F. for 2 hr. Some of them were aged for 100 hr. at 1300° F.; the remainder were left in the solution-annealed condition. Tests were conducted at 1500° F. and 15,000 psi. stress and at 1650° F. and 7500 psi. stress. At 1500° F., the creep rate of the aged material was much lower than that of the solution-annealed material. Initially, this was also true at 1650° F. However, after a short interval the creep rate of the aged material began to accelerate very rapidly. Thus, it appears that the solution-annealed material had the longer rupture life at the higher temperature. The test results also indicated that there is an optimum annealing temperature for



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- Calibrated thermocouples
- Thermocouple insulation
- Thermocouple protecting tubes
- Thermocouple extension wires and cold-end compensation
- Selecting the right thermocouple and protecting tube
- Responsiveness of thermocouples

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AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

Circle 1174 on Page 48-B

Linde Coatings & materials News

LINDE COMPANY, DIVISION OF UNION CARBIDE CORPORATION

Surgical shears get longer life with LINDE tungsten carbide coating

Surgical shears with tungsten carbide coated on working surfaces now lose their cutting edge about *one-third* as fast as conventional shears. This has been proven under rigid testing supervised by a leading research laboratory.

The American Medical Instrument Corporation, Flushing, New York, uses the LINDE Flame-Plating process to improve the working surface and increase the wear-resistance properties of shears produced under its *Tuncarb* trade-mark.

The process has increased cutting life to the extent that *Tuncarb* shears in use for more than a year have not as yet been returned to AMICO for sharpening. By comparison, regular surgical shears used under the same conditions had to be returned as many as three times for restoration of working surfaces.

Coatings only .004″ thick

AMICO ships hot-drop-forged stainless steel parts to LINDE's new Flame-Plating plant at North Haven, Conn. Here, via the LINDE developed coating process, a .004″ thickness of tungsten carbide is actually "welded" to the precision wear surfaces of the instruments.

After coating, the blades and jaws are assembled, riveted, ground, polished, and buffed to a high finish by AMICO. The tungsten carbide surfaces themselves are finished with only a slight brushing. The same process is used to coat *Tuncarb* needle holders to provide tungsten jaws that give a firm grip on needles.

High-speed "blast-on"

The heart of LINDE's coating process is the LINDE Flame-Plating gun, into which exact quantities of oxygen, acetylene, and tungsten carbide or other powdered materials are fed by a special mechanism. After the gun is aimed at the area to be coated, controlled detonations "blast" the particles onto the work piece at speeds up to 2500 fps—until the desired coating thickness is reached.

Although temperatures of about 6000° F are attained within the detonation gun to heat powder to plastic state, the work piece itself is always kept below 400° F during the operation. There are no changes in the properties of the base metal and no distortion of the work piece regardless of its minuteness.

The inside cutting surface of the *Tuncarb* surgical shears shown here have been coated with tungsten carbide, reducing their rate of wear by as much as one-third.

In some uses, depending on the thickness of finish, the LINDE Flame-Plating process has been known to multiply wear resistance of metal parts by as much as 40 times.

For complete information on how you might use this advanced method of coating metals to improve production or reduce operating costs, check and send the coupon below.

LINDE synthetic sapphire solves guide problem in tape recorders

Second only to the diamond in hardness, LINDE synthetic sapphire provides unique wear-resisting characteristics. Because of its extremely low friction, hardness, and physical and chemical stability, several large manufacturers are using LINDE synthetic sapphire to solve the wear problem in tape guides on airborne and high-reliability tape decks, as well as in photographic film guides.

In these areas—where hardened steel guides show friction and wear almost immediately—sapphire wear is nearly imperceptible even after 100 hours of operation.

LINDE flame-polished synthetic sapphire is a convenient material for preventing edge-cutting typical with certain tapes in top and bottom guides.

For details on LINDE synthetic sapphire for any type of wear guide, instrument bearing, or other critical application, check and mail the coupon.

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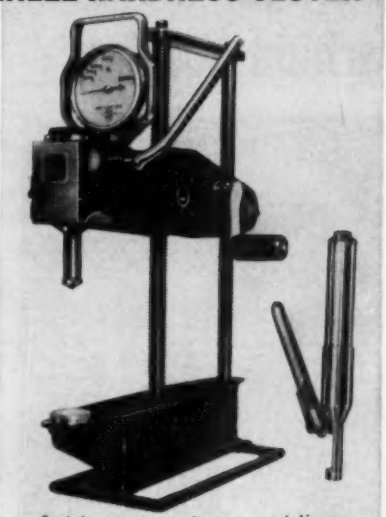

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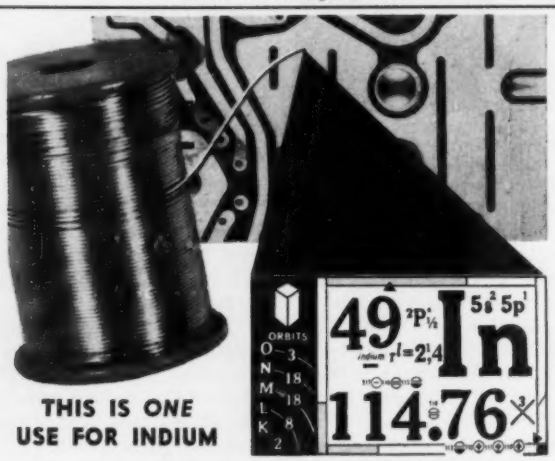

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Reactor Materials . . .

each particular combination of service stress and operating temperature.

The effects of alloying were determined by carburizing Inconel and INOR-8, and comparing them with uncarburized material and with Hastelloy B. Creep tests were conducted on carburized and uncarburized Inconel at 1300, 1500, 1650 and 1800° F. At 1300° F., carburizing reduced the creep rate by a factor of 10 and more than tripled the rupture life. At 1500° F. similar results were obtained. At the higher temperatures the results were even better despite the use of a corrosive environment. This was illustrated by conducting tests in fused salts at 1650 and 1800° F. At 1650° F., the creep rate was reduced by a factor of more than 10, and the rupture life was extended by more than 7. At 1800° F., these factors were 100 and 20, respectively. Similar results were obtained with INOR-8.

The effects of environment were determined by conducting creep tests on Inconel and "A" nickel in air, argon and nitrogen at 1500° F. The service life of coarse-grained Inconel was much greater in nitrogen than in argon, and the creep rate was lower. This was attributed to a reaction between the nitrogen and the metal resulting in the formation of complex nitrides which strengthened the matrix and the grain boundaries. When tested in air and argon, fine-grained Inconel exhibited very little difference in creep rate. However, service life and elongation at rupture were greater in air than in argon.

Tests conducted on "A" nickel in argon and nitrogen revealed no appreciable difference in either creep rate or rupture life—an indication of the importance of an alloying element such as chromium. In air, compared to argon, longer service life and decreased creep rate resulted. For example, at a stress of 1500 psi., nickel failed in an argon atmosphere at 1000 hr. whereas in air the test was discontinued after 10,000 hr. Furthermore, no failure resulted after 8400 hr. at a stress of 2500 psi.

It was concluded that thermal treatment, alloying additions and environment treatment would improve high-temperature strength. Further, optimum benefits are derived by carburization. BERNARD TROCK

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GRAPHITE CORE FOR HANFORD NPR COMPLETED BY NATIONAL CARBON

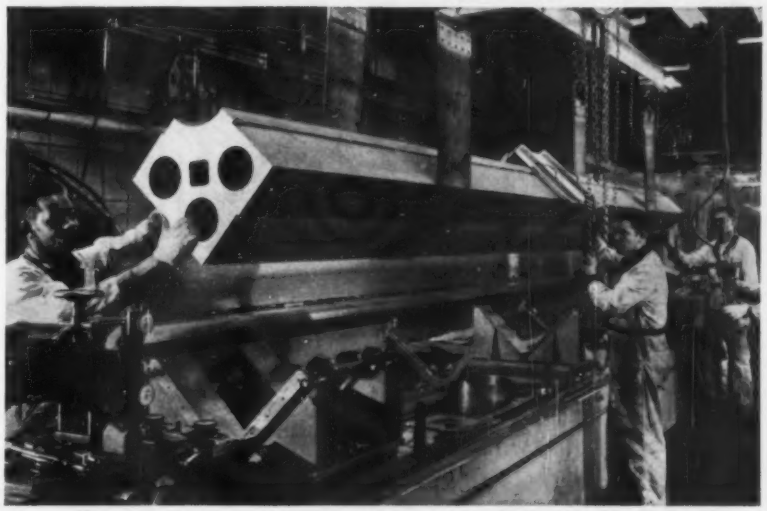
Loading last pallet of moderator bars for the NPR

The task of producing and machining 5 million pounds of high-purity nuclear graphite for the New Production Reactor at Hanford, Washington, has been completed by National Carbon Company.

The entire output was machined to close tolerances, with the thousands of moderator bars ranging in size from 2 x 3 x 48 inches to 6 x 6 x 48 inches. Total ash content was less than 10 ppm.

The New Production Reactor core is another outstanding achievement by National Carbon for the nation's growing reactor program.

4400-lb. graphite columns machined to exacting tolerances for EGCR



Swinging near-20-foot-long EGCR moderator column of "National" nuclear graphite into position for inspection after boring of fuel channels through entire length.

Machining by National Carbon Company of 120 graphite moderator and reflector columns comprising the Experimental Gas Cooled Reactor for the AEC at Oak Ridge, represents a major accomplishment in the production of nuclear components.

General machining specifications for the giant-size columns, designed for the 15-foot, 10-inch diameter core of the EGCR, called for a 125-microinch surface finish. The columns are the longest pieces of nuclear graphite ever produced.

Each moderator column, before machining, measured approximately 20 feet long by 17½ inches square, and weighed some 4400 pounds. Initial machining reduced each column to 16.3 inches square by 19 feet, 4 inches long, with final weight ranging from 2250 to 3600 pounds.

Aside from the boring of numerous precision holes of varying diameters and lengths—such as experimental, control rod, and flux scanning channels; neutron source and thermocouple holes—the most remarkable feat of machining was the boring of the fuel channels. In this operation, 234 holes, 5.25 inches diameter, were bored through the entire length of the columns, with hole diameter held within 0.030-inch, and hole location at each end within 0.010-inch.

After completion of precision machining, each piece passed a purity and flexural load test and was carefully packaged and safely delivered to the customer's plant site.

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Circle 1178 on Page 48-8

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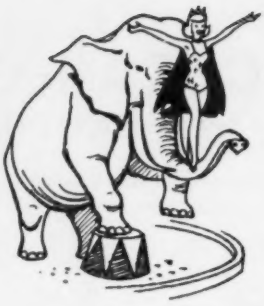

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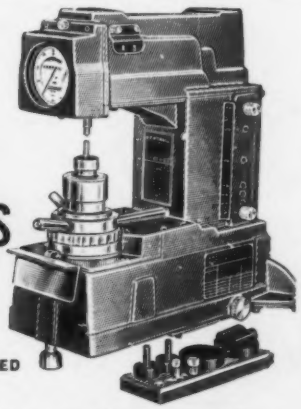

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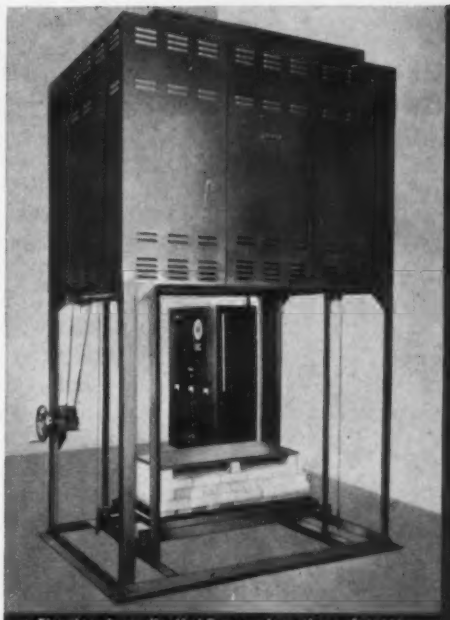

Elevator type Kanthal-Super atmosphere furnace
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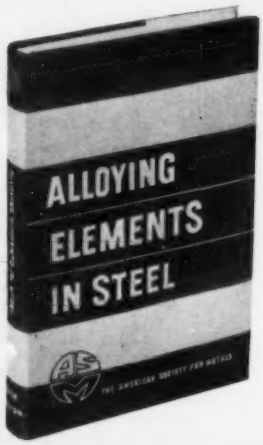

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BEHIND THE BYLINES

This month's issue marks the first appearance of a "guest" Critical Point. Usually a staff-written item, this one is by **G. K. Manning,** technical manager of Battelle Memorial Institute's department of metallurgy, and familiar to our readers as a *Metal Progress* author. Associated with Battelle for 19 years, Mr. Manning was chief of the metallurgical engineering division the last time a write-up appeared in these pages. A graduate of Franklin College (B.S.) and the University of Michigan (M.S.), his work includes such areas as high-temperature alloys and hot work die steels. An aviator in his earlier years, he now says he counts himself lucky to find time for his woodworking. Although he and his wife Dorothy find their lives keyed to their teen-aged daughters, they still have some time to enjoy bridge, square dancing and dramatics together.

In September 1959 we published an article by three staff members of Ford Motor Co.'s Scientific Laboratory on the Ausforming

process. Now, two years later, two of these authors, **V. F. Zackay** and **D. J. Schmatz,** together with **W. M. Justusson,** present an interim report on the process on p. 68. Dr. Zackay (shown, right, in the photo with Mr. Schmatz, left, and Mr. Justusson), who is now assistant manager of the applied science department, graduated from the University of California in Berkeley with B.S., M.S., and Ph.D. degrees in physical metallurgy, and served as an instructor there and as associate professor at Pennsylvania State University. He was named supervisor of the physical metallurgy section at Ford in 1954, where his work has included studies in thermodynamics, alloy design and phase transformation.

D. J. Schmatz, who joined the Scientific Laboratory in 1956, graduated from the University of Wisconsin with a B.S. and M.S. degree in metallurgy. His background includes work on phase transformation and diffusion in steels and alloys and, since joining Ford, development of ultrahigh strength steel. Since the article appeared two years ago, his family has increased by two and he now is busy "entertaining the children and landscaping".

A graduate of Michigan College of Mining and Technology (B.S.) and the University of Wisconsin (M.S.), Mr. Justusson joined Ford in 1954 and is now a supervisor in the research services department. Prior experience includes nuclear work at Westinghouse Atomic Power Div. He lists golf and carpentry as two of his nontechnical interests; during the summer months, he roughs it in the wilds of upper Michigan with his family.

Paul Smits, author of "Testing Protective Coatings on Metals", became interested in methods of testing mechanical and electrical properties of oxide films on aluminum while working on a high-speed continuous anodizing process for aluminum conductor wire

at Aluminum Co. of Canada. His work at Alcan now includes development work on continuous strip anodizing and on colored finishes for aluminum. Born in Amsterdam, Holland, he studied engineering physics and received his M.S. degree from the Federal Institute of Technology in Zurich, Switzerland. As shown by the photo at left, he is an ardent sailor and on summer week-ends can usually be found on Lake Ontario in his "Flying Dutchman" yacht. Winter interests include a classic film club, pottery and collecting paintings.

"Designing a Weldable Alloy Using Metallurgical Parameters" (p. 90) is by **W. N. Platte,** a fellow engineer in the metals joining section of the Westinghouse Research Laboratories. A graduate

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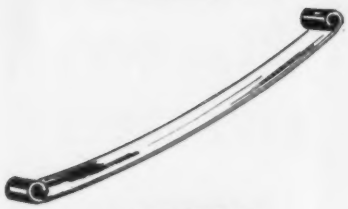

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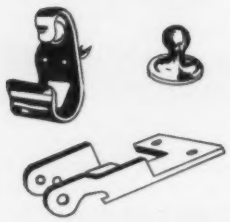

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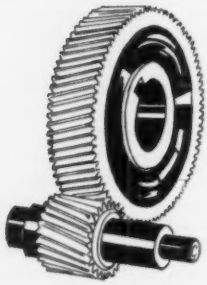

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Circle 1186 on Page 48-B

of the University of Michigan (with a B.S.E. degree in metallurgy) and the University of Pittsburgh (M.S. degree), his work over the past 19 years has been related to many phases of metals joining and includes a number of patents on welding refractory metals and resistance welding.

In the first of a two-part article on alloy 2219, "A New High-Strength Aluminum Alloy" on p. 87, **J. A. Nock, Jr., Marshall Holt** and **D. O. Sprowls** discuss some of the alloy's general characteristics; welding characteristics and weldment properties will be presented in the November issue. After graduating from Penn State in 1923 with a B.S. degree in electrochemical engineering, Mr. Nock joined Aluminum Co. of America and since then has worked on development of wrought alloys and the development of fabricating practices and thermal treatments for aluminum alloys. He was made assistant chief of the physical metallurgy division in 1944 and became chief of the newly formed fabricating metallurgy division in October 1958.

Marshall Holt came to Alcoa's Research Laboratories in 1929 following graduation from the University of Illinois with a M.S. degree in civil engineering, and since then has worked on various types of structural research problems, including columns, thin sheet construction, and pressure vessels. He was promoted to assistant chief of the engineering design division in 1953 and five years later transferred to the mechanical testing division as assistant chief and then chief.

A research engineer in the chemical metallurgy division of Alcoa Research Laboratories, D. O. Sprowls has been with the company since 1936, except for five years absence attending Drexel Institute of Technology where he obtained a B.S. degree in chemical engineering. His work has centered on evaluation of the resistance to corrosion and stress-corrosion cracking of aluminum alloys, particularly in natural environments.

D. C. Herrshaft is the author of both the article on ductile high-temperature brazing alloys on p. 97, the first in our section on Progress in Brazing, and the Data Sheet on Ternary Systems for Ductile

Brazing Alloys just preceding it. After graduating from Rennselaer Polytechnic Institute with a degree in metallurgical engineering, he spent a short time in the Institute's laboratory as a welding research fellow, then went into the air force. Upon his discharge he joined Alcoa Research Laboratories as welding research metallurgist, then G.E.'s transformer division as a welding engineer. He came to Handy & Harman in 1957 and the next year was named assistant manager of the division.

"Calculating Cycles for Brazing" is based on work carried out by **H. M. Lampert** while he was materials engineer at Sundstrand Aviation Div., Sundstrand Corp., Rockford, Ill. The work was done during the development of brazed and welded stainless steel gear and transmission housings for high-temperature aircraft use (B-70 program). Now on the staff of G.E.'s Missile and Space Vehicles Dept., he is a functional engineer in the materials and processes laboratory. The family portrait on the right shows Mr. Lampert with his three sons and daughter—he says family sight-seeing trips are one of his major spare-time activities. He also lists golf, bridge, swimming, bowling and gardening as some of his interests.

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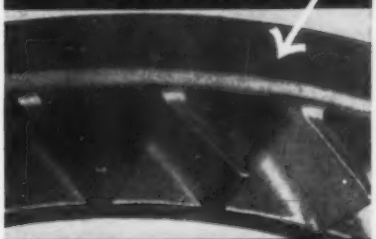

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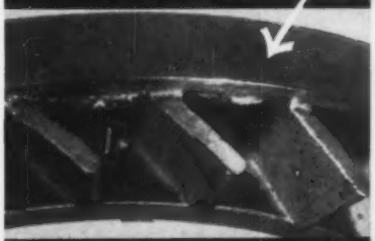

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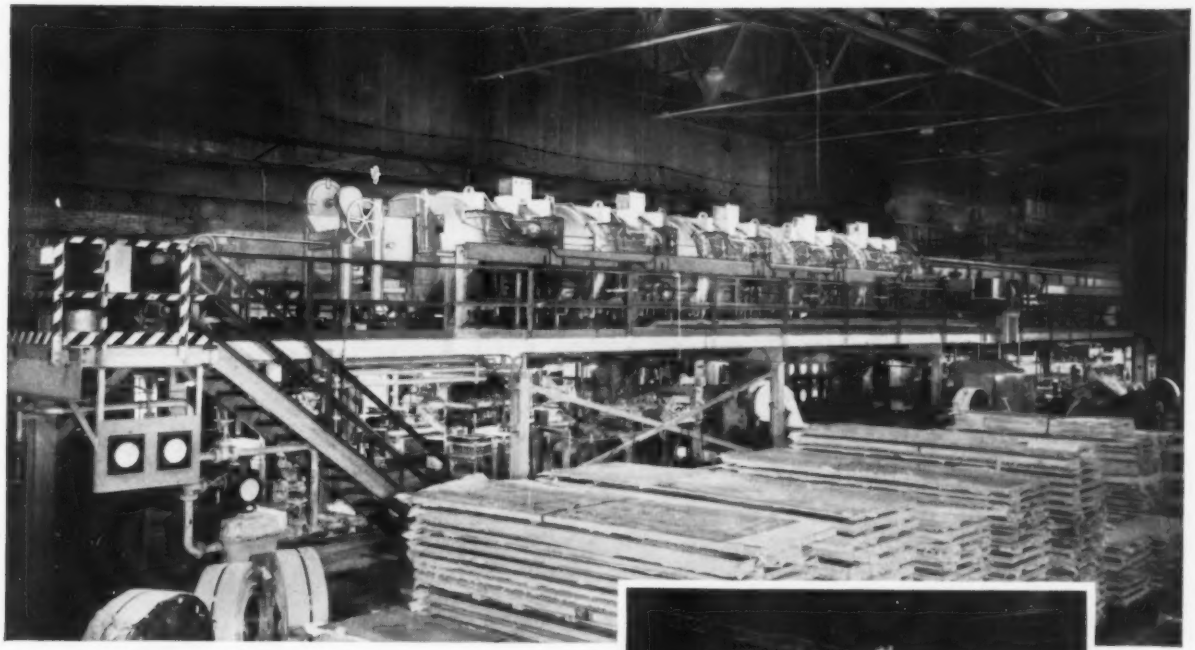

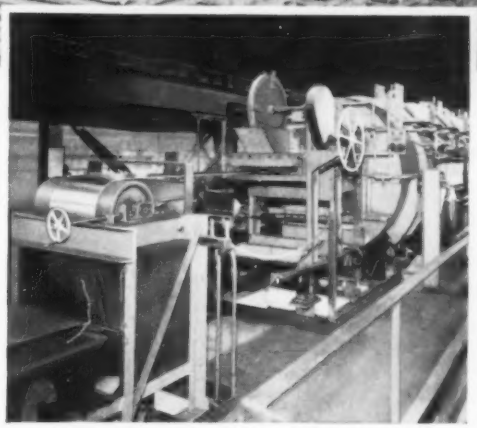

EF Furnace

Bright Annealing Stainless Strip at Armco Steel

• The No. 18, 24" wide Stainless Strip Bright Annealing Line at Armco's Butler, Penna. Works, pictured above, is one of 25 coating, silicon and bright annealing lines, designed and built by The Electric Furnace Co., installed in various Armco plants. Like several other EF horizontal bright annealing lines, the furnace and cooling sections are mounted on a balcony. This permits the pay-off reel, coiling reel and control equipment to be installed under the furnace, saving floor space and minimizing building changes.

EF Stainless Strip Bright Annealing Furnaces produce a durable, mirror finish on trim stock and other stainless strip *without chrome depletion*. The Electric Furnace Co. has designed and built *23 stainless strip bright annealing lines;* this is more than any other manufacturer. Included are both horizontal and vertical type furnaces, fuel fired and electrically heated.

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another torture test for leaded alloy

This guide bushing is a much abused part in a pneumatic rock drill—subjected to severe shock loads and a shattering type of vibrational stress. It is machined from a bar of lead-treated* Aristoloy 8620, carburized and hardened to a 58-63 Rockwell "C". When GARDNER-DENVER switched to lead-treated steel, they happily discovered production jumped 42%. Feed rates, drilling, turning, forming, boring, and cut-off operations could also be increased. Tool life was extended 20 pieces between grinds.

For complete information about how you can get alloy steel strength in free-machining steel, call your nearest Copperweld representative. Or write for Leaded Steels Catalog and Products & Facilities Catalog.

*Inland Ledloy License

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